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THE ETHICS OF CLIMATE ENGINEERING

REPORT • Adopted in November 2023

COMEST World Commission on the Ethics of Scientific Knowledge and Technology

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SHORT SUMMARY

Should we engineer the climate?

Climate change is one of the defining issues of our time.

Latest studies from the IPCC (Intergovernmental Panel on Climate Change) show that the **1.5°C warming threshold could be reached as early as 2030, increasing the risks of extreme and irreversible climate effects**.

The current speed of global warming is giving a strong impetus to consider all options available to counter the heating effect of greenhouse gases, including the most uncertain ones such as climate engineering. Yet, the emergence of these technologies has given rise to **fundamental ethical questions** about their potential implications on human and natural systems.

3.6 billion people already live in areas highly susceptible to climate change

For the first time, a Report by the **COMEST** (World Commission on the Ethics of Scientific Knowledge and Technology) presents a **comprehensive global ethical perspective on climate engineering**, with a thorough assessment of the ethical, social, and cultural implications of these technologies.

Based on the identified ethical challenges, COMEST also puts forth concrete recommendations for Member States and all relevant stakeholders – including scientists, policymakers, affected communities, and the public – to address the research and potential development of climate engineering technologies in a transparent and inclusive manner.

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"Since wars begin in the minds of men and women it is in the minds of men and women that the defences of peace must be constructed"

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FOREWORD

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Climate change is the defining challenge of our lifetime. With one record-breaking temperature after another, the effects of climate change become increasingly pronounced worldwide. As time runs out, we cannot rule out any option to counter these worrisome developments and put us on the right path.

Climate engineering is one of such options, referring to a set of methods and technologies that aim to deliberately alter the climate system. With the potential to stabilize and even reduce global temperatures, it could have the potential to become a tool in alleviating climate impacts.

However, as with all new and disruptive technologies, this rapidly evolving field has also brought up some profound ethical questions. Actually, the very notion of considering climate engineering as a potential solution to climate change is an ethical question. Concerns exist that it may be a techno-fix solution to a much bigger issue, leading to the risk of diverting resources away from emissions reductions and adaptation efforts. Moral hazard issues also play a role, as climate engineering may also cause a relaxation of the efforts.

Second, the lack of comprehensive research on their environmental and human impacts has sparked fears of unintended consequences. It has also fuel misinformation and even conspiracy theories on weather manipulation.

Finally, current governance systems, particularly at the international level, are not fit for purpose to deliver inclusive outcomes. Besides, the transboundary nature of these technologies has the potential to trigger geopolitical tensions: climate knows no frontier, and, in this field, any action done in one country inevitably affects others. A coordinated, multilateral approach that brings all voices around the table is crucial for effective oversight.

In this context, UNESCO's World Commission on the Ethics of Scientific Knowledge and Technology (COMEST)'s report on the Ethics of Climate Engineering is timely and relevant. Building upon UNESCO's unique ethical mandate, and a track record of three decades delivering on evidence-based analysis, the analysis sheds light on the various risks these technologies raises, and concludes that their benefits must be weighed against broader societal, ethical, and cultural implications.

In presenting here an in-depth assessment of the implications of climate engineering technologies and practical recommendations to guide normative action, this report puts into practice the UNESCO Declaration on the Ethical Principles in relation to Climate Change (2017), which calls upon global partners to mobilize around ethical principles to guide decision-making and policy development to address climate change at all levels.

In the context of declining trust in science, we need to promote inclusive and transparent debate at all levels and raise public awareness - especially regarding these potentially world-changing technologies. The climate emergency must not make us forget that the discussion around climate engineering is not merely a technological debate: it is above all a societal debate.

UNESCO is committed to working with Member States and all stakeholders to continue to frame this debate, ensuring that any decisions taken on climate engineering technologies are well-informed and ethically sound, upholding human rights and fundamental freedoms.

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for Social and Human Sciences,
UNESCO

Within the framework of its work programme for 2021-2022, the World Commission of UNESCO on the Ethics of Scientific Knowledge and Technology (COMEST) decided to address the topic of the ethics of climate engineering, building on its reflection on climate change and environmental ethics and following its reports on Water Ethics: Ocean, Freshwater, Coastal Areas (2018) and on Land-use Ethics (2021).

At the 11th (Extraordinary) Session of COMEST, held online in February 2021, the Commission established a Working Group to develop an initial reflection on this issue. The Working Group met online twice in October 2021 to define the structure and content of its text. In preparation for the 12th (Ordinary) Session of COMEST, held online from 29 November to 3 December 2021, the Working Group prepared a Concept Note providing a synopsis of its reflection thus far, which was presented and discussed at the public meeting of the session on 3 December 2021.

Consequently, the Working Group continued its reflection on the topic during an online meeting in May 2022, where it further developed the structure of the report. The above-mentioned Concept Note was presented once again to the 12th (Extraordinary) Session of COMEST from 19 to 23 September 2022, in which the Commission provided an update of their reflection thus far. During that session, COMEST decided to continue its work on the topic as part of its work programme for 2022-2023.

Taking into account comments and feedback received during the above-mentioned session and in preparation for the 13th (Ordinary) Session of COMEST from 18 to 22 September 2023, the Working Group met online in March 2023 and in person in Italy in May 2023. At this meeting, the discussion of the Working Group was enriched by a public symposium held jointly by UNESCO and the Instituto Universitario di Studi Superiori (IUSS - University School for Advanced Studies), Pavia. The final draft of the report was prepared during the above-mentioned working group meetings, revised during the 13th (Ordinary) Session of COMEST and adopted by the Commission during an online plenary meeting on 28 November 2023.

This document does not pretend to be exhaustive and does not necessarily represent the views of the Member States of UNESCO.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The report discusses climate engineering technologies, their technical and ethical dimensions, the risks involved, as well as ethical issues and challenges related to climate engineering research and governance.

Four lenses for ethical reflection on climate engineering

- **Human-ecosystem interconnectedness** highlights the need to consider the potential impacts of climate engineering on ecosystems and biodiversity, as well as the ethical responsibilities towards future generations and the overall health of the planet.
- **Intergenerational ethics and justice** raises questions about the long-term consequences and fairness of deploying climate engineering technologies and the potential risks they may pose for future generations.
- **Proportionality** requires evaluating whether the intended goals of climate engineering justify the potential risks, trade-offs, and unintended consequences that may arise, considering both short-term and long-term impacts.
- **Distributive justice** involves considerations of fairness, equity, and access to resources, ensuring that the implementation of climate engineering technologies does not disproportionately impact vulnerable communities or exacerbate existing inequalities.

The very idea of climate engineering

- **Carbon Dioxide Removal** (CDR) approaches have the potential to directly remove carbon dioxide from the atmosphere, helping to mitigate climate change by reducing greenhouse gas concentrations. These methods can store carbon dioxide permanently, contributing to long-term carbon sequestration. Some CDR approaches, such as reforestation and ecosystem restoration, have additional benefits such as restoring biodiversity, improving water quality, and enhancing soil health. Many of these methods act slowly and may take a considerable amount of time to have a significant impact. Certain approaches, such as tree planting, may have limitations in terms of available land, resources, and potential conflicts with land use for agriculture or human settlements. Moreover, some CDR methods may have unintended adverse impacts on ecosystems, such as invasive species introduction, altering natural habitats, or disruption of local biodiversity.

- **Solar Radiation Modification** (SRM) techniques can potentially provide a rapid reduction in global temperatures by reflecting or blocking a portion of sunlight, providing a short-term cooling effect. These approaches may be considered as a temporary measure in situations where there is an urgent need to prevent or alleviate the impacts of extreme climate events or to buy time for emissions reductions and other climate adaptation measures. The efficacy, side effects, and potential unintended consequences of SRM approaches are not yet fully understood. For example, altering solar radiation may disrupt weather patterns, impact precipitation, and have regional climate effects that could affect ecosystems and agriculture. SRM interventions raise ethical questions concerning power imbalances, accountability, and the control and governance of climate-altering technologies. The potential for geopolitical tensions and conflicts may arise if unilateral or unregulated deployment of these methods occurs. Moreover, SRM does not address the underlying causes of climate change, namely the high levels of greenhouse gas emissions. Its effectiveness relies on continuous implementation and could create a dependency on the technology without reducing emissions.

Ethical issues and challenges

- **The slippery slope argument** suggests that by deploying climate engineering, society may become reliant on these technologies and neglect other essential climate actions, such as reducing greenhouse gas emissions. This argument raises concerns about the potential diversion of resources and attention away from sustainable mitigation and adaptation efforts.
- **The moral hazard argument** suggests that climate engineering could create a sense of false security, leading to reduced efforts to mitigate climate change at their source. Deploying these technologies without also addressing the root causes of climate change may undermine the incentive for reducing greenhouse gas emissions and transitioning to renewable energy sources.
- **The organized irresponsibility argument** questions who should have the authority to make decisions about deploying these technologies, how their impacts should be monitored and regulated, and how potential unintended consequences should be mitigated. Ethical considerations include ensuring transparent decision-making processes and robust governance mechanisms.
- **The economic challenges argument** raises questions about the feasibility and affordability of deploying large-scale climate engineering projects, as well as the potential distributional effects on marginalized communities. Ethical considerations involve assessing the economic impacts, ensuring equity in access to these technologies, and preventing exacerbation of socio-economic inequalities.

Ethics of climate engineering research

- **Scientific expertise does not simply translate into policy advice**. Decision-makers often face the challenge of navigating conflicting policy proposals with evidence and counterevidence. Recognizing this interdependence helps ensure that scientific research is effectively integrated into the decision-making process.
- **Media** have the power to frame public discourse and shape the narratives surrounding climate engineering. The way they present and communicate information can influence public perceptions, values, and attitudes towards climate engineering research. Responsible media reporting takes into account scientific consensus, uncertainties, and potential risks, while also highlighting societal implications and ethical considerations.
- Media plays a critical role in **holding researchers and institutions accountable** for their actions and decisions in climate engineering research. Through investigative journalism and critical reporting, the media scrutinizes and brings attention to ethical, social, and environmental issues associated with the research. This helps ensure transparency, accountability, and responsible conduct in climate engineering research.

Ethics of climate engineering governance

- Governance should ensure **accountability and transparency** in the development and deployment of climate engineering technologies. Clear mechanisms for monitoring, reporting, and evaluating the impacts of these interventions should be established to ensure that they are implemented responsibly and ethically.
- The governance framework needs to establish a **legitimate and inclusive decision-making process** that involves input from various stakeholders, including scientists, policymakers, affected communities, and the public.
- The governance of climate engineering requires the development of **effective regulations and legal frameworks** that address the potential risks, unintended consequences, and ethical implications of these technologies. This includes establishing international agreements and guidelines to guide their research, development, and deployment.
- Since climate engineering has the potential to have transboundary impacts, effective governance should facilitate **international cooperation and coordination**. This includes developing mechanisms for sharing information, collaboration in research and development, and addressing potential conflicts of interest among different nations.

Recommendations

- **Governance**: Decision-makers must engage openly and responsibly in monitoring climate action, including climate engineering, and ensure that decisions are made with environmental benefits in mind and are fair to present and future generations. Scientific facts, technological specificities, uncertainties, cultural influences and risk distribution should be taken into account when making decisions on climate engineering. Member States need to develop laws to regulate climate engineering that are aligned with international standards. They must also be aware of their global impact, promote international and intercultural dialogue and foster regional cooperation for balanced environmental impacts. Additionally, climate engineering proposals must include mitigation strategies and the weaponization of such technologies must be universally banned.

- **Participation and Inclusiveness**: A wide-ranging, collaborative approach is needed in climate action, from international to local community levels. It's important to involve and encourage civil society and citizens to participate and influence government decisions. Special attention should be given to ensuring that vulnerable groups, women, youth, and indigenous people are included and their needs are considered in all climate action decisions.

- **Role of Scientific Knowledge and Research**: Research on climate action, including climate engineering, should be unbiased and aim to clarify the effectiveness and risks of various technologies. This research should span indoor studies, simulations, and small-scale outdoor experiments, all conducted ethically and transparently. Decisions on climate action must be based on solid scientific evidence and involve different scientific disciplines. Sharing research findings globally is essential for informed decision-making and public debate. Regular monitoring of the impacts of climate action is also crucial.

- **Strengthening Capacity**: Member States should boost their capabilities in managing climate action and climate engineering, focusing on improving their institutions, technologies, and ethical understanding. This involves supporting public and civic training and collaborations. Additionally, businesses and industries should act responsibly, adhere to international standards, and work closely with governments and international organizations in climate-related initiatives.

- **Education, Awareness, and Advocacy**: UNESCO should promote the inclusion of ethical climate action and climate engineering topics in educational programs. It's also important for UNESCO to lead in raising public awareness about the ethical challenges and uncertainties in climate actions. This includes highlighting the need for public participation and informed decision-making in these areas.

I.
INTRODUCTION AND ETHICAL FRAMEWORK

I.1. Introduction: Goals of climate action and climate engineering

1. The current speed at which the effects of global warming are increasingly being manifested is giving new life to the discussion on the kinds of climate action that are best suited to tackle the catastrophic consequences of climate change. The temperature targets adopted as part of the Paris Agreement in 2015 gave new attention to a highly controversial set of proposals of potential climate engineering actions. So-called climate engineering measures seek to counteract global warming not by cutting greenhouse emissions, but by intervening in the climate system directly, either by drawing carbon dioxide (CO_2) from the atmosphere (carbon dioxide removal, or CDR), or by allowing more infrared radiation to escape into space or reflecting incoming sunlight back to space (solar radiation modification, or SRM)[1]. While SRM approaches are presently the more controversial of the two approaches, some experts have begun to suggest that these measures, too, might become necessary to avoid dangerous climate tipping points or to bring temperatures back down after an overshoot[2].

2. In the light of the development of such climate-altering technologies, calls for a thorough assessment of the ethical, social and cultural implications of climate engineering have grown louder. With this report, the World Commission of UNESCO on the Ethics of Scientific Knowledge and Technology (COMEST) responds to these demands. Building on the set of reports on ethical principles for climate change already developed in 2010-2015, this report focuses on developing a comprehensive perspective on the ethics of climate action, specifically, climate engineering.

3. UNESCO has already considered issues related to climate change in some reports and standard-setting instruments. Most notably, these include:

    a. In 2010, the Intergovernmental Oceanographic Commission (IOC) of UNESCO commissioned a report on ocean fertilization: *Ocean Fertilization: A Scientific Summary for Policy Makers* by Doug Wallace et al. (UNESCO, 2010).

    b. The set of reports of COMEST on ethical principles for climate change (UNESCO, COMEST, 2010-2015).

    c. In 2017, the Member States of UNESCO adopted a Declaration of Ethical Principles in relation to Climate Change (UNESCO, 2017), which presents a list of criteria that should guide decision-making in all areas of climate policy, including damage

1 Other commonly used terms are geoengineering (Royal Society, 2009), climate intervention (NRC, 2015a, 2015b) or climate-intervention technologies (American Geophysical Union, 2022). In this report, we use 'climate engineering' to highlight our focus on measures that seek to deliberately alter the global climate system in order to counteract global warming. We use the term as an umbrella to include both CDR and SRM approaches.

2 A temperature overshoot scenario refers to global mean temperature temporarily exceeding a specific target, such as 1.5°C.

prevention, a precautionary approach, equity and justice, sustainable development, solidarity, as well as recognizing the importance of scientific knowledge and integrity in decision-making.

4. Relevant authoritative assessments and regulatory documents on climate engineering include (among several others):

a. The Royal Society (2009). *Geoengineering the Climate: Science, Governance and Uncertainty.*

b. The de facto moratorium on climate engineering by the United Nations Convention on Biological Diversity in 2010 (decision X/33 and IX/16 C).

c. The prohibition of ocean iron fertilization by the London Convention and Protocol in 2013 (resolution LP.4(8)).

d. United States National Academies of Sciences, Engineering and Medicine (NASEM) (2015a). *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration.* The National Academies Press.

e. United States National Academies of Sciences, Engineering and Medicine (NASEM) (2015b). *Climate Intervention: Reflecting Sunlight to Cool Eart*h. The National Academies Press.

f. United States National Academies of Sciences, Engineering and Medicine (2021). Reflecting Sunlight: *Recommendations for Solar Geoengineering Research and Research Governance*.

g. The statement on the need to accelerate action on climate change, issued by the Royal Society together with the world's leading scientific academies in May 2021.

h. The report One Atmosphere: *An Independent Expert Review on SRM Research and Deployment* by the United Nations Environment Programme (UNEP) in March 2023.

i. The report *Reducing the Risks of Climate Overshoot* presented by the Climate Overshoot Commission in September 2023.

5. All these assessments and normative documents are evidence of the great concern worldwide on the topic of climate action, and can be considered as a shared set of ideas on the climate crisis and ways to deal with it. In this sense, these documents inform this report's task of providing a global ethical perspective on climate actions, with specific reference to climate engineering.

6. Ethical evaluation of climate engineering techniques requires a consideration of each technology in itself, including the level of scientific knowledge on which it is based, its cultural assumptions, as well as the distribution of risk in terms of decision-making, impact, and governance. Such evaluation takes place in the context of considering the balance between a policy of *not doing* (i.e. avoiding the most environmentally damaging human activities) and *doing* (in line with the goal of alleviating the most severe effects of ongoing climate change).

7. The structure of the report is as follows: In the rest of this section we introduce four lenses through which to consider the ethics of climate action (human-ecosystem interconnectedness, intergenerational ethics and justice, proportionality, and distributive justice); **Section II** offers explanations of the idea of climate engineering, the evolution of definitions of concepts used in international debate on climate engineering, and a list of numerous and different technologies which are encompassed under the umbrella concept of climate engineering; **Section III** highlights the state-of-the-art of the ethical discussion around climate engineering, and presents the recurring arguments in the debate about climate engineering (such as the slippery slope argument, moral hazards, among others.); **Section IV** discusses the ethics of science and research in climate engineering, starting from freedom of scientific research and the role of scientific knowledge to the responsible research and innovation perspective; **Section V** is devoted to ethics and governance issues in climate engineering, starting with reflections on justice, human rights and moral responsibility or moral impediment, and moving to issues of governance and regulation of climate engineering (including the participation of civil society). The report concludes with a list of **recommendations** which offers suggestions about normative ethics in regard to climate engineering.

I.2. An ethical framework for reflection on climate actions

8. Any reflection on climate change and actions to address it can be seen as an inherently ethical reflection, since reflecting on climate action implies reflecting on conflicting interests not only between regions and countries, but also social groups. As such, any reflection on climate engineering is both an ethical and a political one.

9. This situation implies that risk analysis should be a core driver of decisions on climate action, and that a way to determine when one might consider an action to be ethically justified on a spectrum of risk analysis of climate challenges needs to be found. The following constraints on such analyses and realizing this aim should be taken into account. Firstly, such analyses move along a dynamic and often unpredictable spectrum, given the political complexity and scientific uncertainty of factors to be considered. Consequently, there might be different, (partially) morally defensible, but incompatible ethical approaches to navigate (Taebi et al., 2020), and thus, there are also normative uncertainties related to risk decisions in climate strategy contexts. Secondly, if the climate change situation becomes critical, we might need to consider implementing measures which carry a greater risk than we might be comfortable with, and we might not be able to agree on an option that is fully morally defensible.

10. Given this situation, normative guidelines which enable a clear justification of any option decided on at any given time become imperative. In this sub-section therefore, we highlight four lenses as a framework to inform reflection on when a climate action might be deemed to be ethically justified. These lenses speak to the uncertainty and complexity of motivations for climate action decision-making.

I.2.1. Beyond the anthropocentrism vs. ecocentrism debate

11. Given the current and expected future harm to the environment, should all concerns be focused on potential future harm to human welfare, or should ethical consideration focus on the moral responsibility humans have towards the environment first, and to humans second? Given the shared impact of climate change on humans, non-humans and the environment, we argue for a view of human-ecosystem interconnectedness and flourishing.

12. The separation of humans from nature inscribed in anthropocentricism is a particular normative framework with ancient Western roots which could imply that climate actions should benefit humans without considering the broader impact on the planet. This seems counterintuitive, as after all, it is the status of our planet that is causing this reflection on climate action and "our very existence depends on a sustainable natural environment" (Brennan & Norva, 2022). That said, it must be acknowledged that Western thinkers have over time reflected in various ways on the problem of anthropocentrism (e.g. Kopnina et al., 2018). This reflection has gone some way towards closing the big split between anthropocentrism and ecocentrism, albeit not entirely (specifically in the political sense).

13. Ecocentrism – the view that values nature for its own sake – also has ancient roots, mostly in the East and the Global South. This view implies valuing the interdependence of humans and non-humans and their dependence on the flourishing of the environment and ecosystems Some Eastern philosophies (e.g., Chinese Daoism, Buddhism) and African philosophies (*Ubuntu*), might offer a way to overcome the dichotomy between anthropocentricism and ecocentricism.

14. According to Daoism, the balance between humans, animals and the universe (*dao*) is core to our well-being and 'life-energy'. It is also in Daoism that we find the notion of *wu-wei* (no action), which points to humans not disturbing natural processes and embracing the view that nature is not a separate resource simply waiting for humans to exploit (Kuo, 2011) but rather part of the interconnected web of life.

15. According to Ubuntu, there is a close relationship between humans and the environment and ecosystems. A person is a person through other persons, where 'other persons' can be reinterpreted as referring to other humans, non-humans, and nature. Thus, the notion of community in Ubuntu also prescribes the interconnectedness of humans and nature. When one considers 'others' also to include non-humans and nature, the notion of *ubuntu* is extended to that of *ukama* which refers to relatedness as found in the cosmos (Terblanché-Greeff, 2019).

16. Considering the ethics of climate action through approaches which view humans and the environment as an interwoven unit can enrich and inform efforts to go beyond the anthropocentric/ecocentrism debate on climate action in many ways, as such approaches illustrate that humans, non-humans, and nature should not be separated; neither should either one be exclusively in the service of the other. We argue that such an approach based on human-ecosystem interconnectedness should be given proper consideration as a guideline in serious discussions on the ethics of climate action, and should be one of the lenses through which reflection on ethical concerns of climate action takes place.

I.2.2. Intergenerational ethics and justice

17. Intergenerational ethics focus1es on what – if anything – current generations owe (past and) future generations. This domain of ethics originated in the context of climate science for obvious reasons, given the bleak outlook for humanity in the context of climate change if nothing is done, on the one hand, and on the other hand, the potential impact of various climate change options, such as climate engineering, on a future world.

18. In the domain of intergenerational ethics, the general aim is to remain aware both of the necessity and of the difficulties of determining the needs and interests of future generations, while navigating the debate on whether future generations may be said to have any rights at all (Gosseries, 2001).

19. Intergenerational ethicists work to understand and define issues affecting intergenerational justice by analysing and reflecting on the extent and nature of relations among different generations. Two of the core questions they consider are:

- **a.** Do we have a moral obligation to future generations at all? If so, what do we owe them?
- **b.** How do we know what the values to be bequeathed to future generations and driving intergenerational justice should be, given the power asymmetry between current and future generations and the fact that there is no "direct reciprocity" between contemporary and future generations (see, e.g., Meyer, 2021)?

20. We argue that climate change threats to human flourishing in general, and to social stability and justice in particular, should be considered through an intergenerational ethics and justice lens as this would contribute to establishing concrete measures to underpin the ethics of climate engineering and guide decisions on climate action in general.

I.2.3. Proportionality

21. Proportionality relates to only acting under certain conditions. *The Practical Guide to Humanitarian Law* (Médecins Sans Frontières, n.d.) describes the principle of proportionality as "a core principle in international law, which provides that the legality of an action shall be determined depending on the respect of the balance between the objective and the means and methods used as well as the consequences of the action". Proportionality is also a principle that plays a central role in UNESCO documents, for instance, the UNESCO Recommendation on the Ethics of Artificial Intelligence (2021) highlights the importance of taking context into consideration when using proportionality as a guideline.

22. This principle points to the importance of factoring cultural diversity, gender perspectives and, specifically, geopolitical differences into ethical reflections on climate action. Considering the ethics of climate action through the lens of proportionality acknowledges that any attempt at a risk assessment framework should take into account "uncertainty and scale" (Jones, 2003). This implies that reflecting on or addressing climate action concerns, while best done in a probabilistic framework, should also always heed the warning that it is not only scientific uncertainty that is at issue, but also normative uncertainty (see next paragraph).

23. Some authors warn that "climate risks cannot be simply portrayed or calculated as a function of probability and consequence, precisely because they are essentially 'systemic risks' that involve uncertainty and ambiguity" (Taebi et al., 2020). Importantly, the uncertainty at issue is not only limited to the scientific and technical domains, but also includes normative uncertainties. Therefore, as mentioned in Section I.1, it might turn out that proposed climate change solutions might require deciding among different, but incompatible and partially morally defensible options (Taebi et al., 2020).

24. Considering the ethics of climate action through a proportionality lens implies acknowledging that decision-making is a complex and dynamic issue and that if the climate change situation becomes critical, decisions might need to be made that are the best at the time, given the nature and extent of scientific and normative uncertainty at that time, rather than being either fully morally defensible or risk-free. This is precisely why an ethical framework guiding climate engineering decisions is essential.

I.2.4. Distributive justice

25. In its broadest sense, the concept of distributive justice refers to how individuals judge what they receive. More specifically, distributive justice considers the fairness of the distribution of resources and responsibilities, or benefits and burdens, across societies. The three main elements in distributive justice debates are proportionality, fairness and equality.

26. Distributive justice concerns are raised in the context of the ethics of climate action because of the unequal global distribution of elements contributing to sustainability, such as infrastructure, scientific expertise, economic resources and governmental capacity.

27. Two main concerns have been identified in this context. The Just Target Question, which relates to "what balance to strike between ensuring that moral subjects are not harmed by climatic changes and ensuring that the policies required to prevent harmful climatic changes are not unduly onerous" (Caney, 2018). The second concern is the Just Burden Question which invites us to reflect on "how the costs involved in combating dangerous climate change should be distributed among duty-bearers" (Caney, 2018).

28. It is also useful in such reflections on distributive justice to consider the problem of the tragedy of the commons according to which entities with access to a specific resource maximize their own self-interest and as a result might deplete the resource, resulting in potential harm for other entities. One principal issue in this context is to consider how to allocate emissions rights, given the overshoot scenario (Meyer & Roser, 2006).

29. There is no one-size-fits-all ethical response to these concerns. We argue that at the minimum, considering climate action through a distributive justice lens implies that there should be recognition that concerns about social justice – including distributive justice – in the climate change context should never be considered in isolation from one another, but be considered as an interactive mutually impacting dynamic (Caney, 2018).

II.

CLIMATE ENGINEERING: THE VERY IDEA

II.1. Climate engineering and climate action in context

30. Anthropogenic climate change is one of the most pressing societal issues of our time. For decades, scientists have been concerned with human impacts on the climate, warning policy makers and the public of the potentially catastrophic impacts that growing levels of atmospheric greenhouse gases might have on human societies and their natural environment. The latest scientific consensus, as represented by the Intergovernmental Panel on Climate Change (IPCC), is that human activities are the main driver of climate change: "Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850–1900 in 2011–2020" (IPCC, 2023). The largest sources of anthropogenic greenhouse gases are the burning of fossil fuels, land use and agricultural practices, as well as industrial processes.

31. Experts have proposed different actions to address the various threats posed by anthropogenic climate change. These *climate actions* can be classified according to their *mode of intervention* regarding the problem at hand:

a. *Mitigation* refers to approaches that intervene in the human actions which cause climate change, i.e., by drastically cutting anthropogenic greenhouse gas emissions (mainly carbon dioxide and methane).

b. *Adaptation* refers to approaches that intervene in the adverse effects that climate change has on human societies, e.g., by making built infrastructures more resilient to rising sea levels, severe droughts, or heavy rains. Adaptation thus importantly differs from mitigation as it seeks to adapt human societies to the *effects* of a changing climate rather than attempting to halt climate change itself.

c. *Climate engineering* refers to approaches that aim to intervene deliberately in the climate system in order to halt, slow down or reverse global warming. Two groups of climate-altering technologies are generally distinguished in this context:

i. Carbon dioxide removal (CDR) seeks to remove CO_2 from the atmosphere and durably store it in geological terrestrial, or ocean reservoirs, or in products. In some ways, CDR might be considered to redress the root cause of climate change.

ii. Solar radiation modification (SRM): through atmospheric interventions that either reflect more sunlight back into space or allow more infrared radiation to escape into space, these techniques could offset the effects of increased greenhouse gas concentrations.

32. In order to have a measurable impact on climate change, climate engineering needs to be deployed on a large scale. A considerable amount of research is being undertaken on climate engineering methods in several countries, and some technologies, particularly CDR approaches, are already in development – and in pilot stages, although not at scale.

33. It is important to stress that, within the portfolio of climate actions, only mitigation addresses the human causes of climate change. Drastically cutting greenhouse gas emissions is therefore absolutely necessary to halt dangerous climate change—all other approaches are additional or complementary, and do not serve as a replacement for decarbonization.

II.2. Words, concepts, and their evolution

34. Climate engineering approaches have been included in high-level climate policy frameworks since the 1960s, and this means since the very beginning of this policy field (for some of the earliest references to climate engineering measures, see, e.g., PSAC, 1965; NRC, 1977; IPCC, 1995). Only since the early 2000s, however, has climate engineering taken on a broader political significance. In particular, the Paris Agreement of 2015 brought these approaches widespread policy attention, when experts argued that in order to halt dangerous global warming in time, it might be necessary to complement mitigation efforts with climate engineering, and especially with CDR approaches. This argument is premised on a significant gap between (a) what experts consider as a meaningful climate policy goal, and (b) what experts assume to be the reductions in atmospheric greenhouse gas concentrations needed to attain this goal.

35. The Paris Agreement states the goal of holding "the increase in the global average temperature to well below 2°C above pre-industrial levels". *A Special Report on Global Warming of 1.5 °C*, published by the Intergovernmental Panel on Climate Change (IPCC) in 2018, served to support this target scientifically, warning of the severe impacts to be expected from warming even beyond 1.5 °C above pre-industrial levels. The report, however, also suggests that this goal is not compatible with the national commitments to emission reductions that the Parties have submitted under the Paris Agreement (nationally determined contributions – NDCs). According to the experts, attaining this goal would require reducing emissions by 45% by 2030 and reaching zero emissions by mid-century (IPCC, 2018).

36. In order to produce pathways that would be compatible with the 2°C target, despite the lack of existing emission-reduction commitments, experts introduced so-called "negative emissions technologies" (NETs) into their models, i.e., capacities to draw carbon emissions out of the atmosphere. This not only gave rise to the concept of "net-emissions" and "net-zero emissions" as a new defining framing for long-term climate governance. It also pushed CDR concepts, which had received little policy attention thus far, to the heart of climate policy (see, e.g., Beck & Mahony, 2018). As a result, the Paris Agreement turned CDR into a central means to complement emissions reductions in reaching climate policy targets and compensate for greenhouse gas emissions that are at present hard to abate ("residual emissions"). A rich body of literature has drawn critical attention not only to the speculative nature of claims to reach "negative emissions" at scale (the technologies to deliver these negative emissions at scale do not exist yet), but also to the embedded politics of global models that systematically prioritize negative emissions over short-term emissions reductions owing to the economic assumptions upon which they are based (Beck & Mahony, 2018; Carton, 2020; Van Beek et al., 2022; Lund et al., 2023). This literature has emphasized the sensitivity to normative assumptions by integrated assessment models used to evaluate the technological and economic feasibility of climate goals such as the Paris Agreement's long-term temperature goal, especially their built-in goal of long-term cost-optimization and choice of discount-rate, which remain largely hidden in the communication of their outputs.

37. IPCC, in its Fifth Assessment Report, defined climate engineering as "a broad set of methods and technologies that aim to deliberately alter the climate system in order to alleviate the impacts of climate change" (IPCC, AR5). Climate engineering was then divided into CDR and SRM.

38. The Sixth Assessment Report of IPCC (AR6) has significantly modified this classification. It states that "while solar radiation modification (SRM) and carbon dioxide removal (CDR) were often referred to as 'geoengineering' in earlier IPCC reports and in the literature, the Special Report on Global Warming of 1.5°C of IPCC (SR1.5) has started to explore SRM and CDR more thoroughly and to highlight the differences between – but also within – both approaches more clearly" (Patt et al., 2022). The AR6 also proposes classifying CDR as a form of mitigation rather than climate engineering. This change reflects the fact that climate engineering is a fluid concept, the definition of which is subject to modifications and debate. The literature has suggested that defining climate engineering is more than a mere technical issue, but in fact implies a "de facto governance" of the respective measures, delineating and highlighting important regulatory and governance dimensions while hiding others (Boucher et al., 2014; Gupta & Möller, 2018).

39. The recent redefinition by IPCC, which no longer considers CDR as a form of climate engineering, is controversial, as it normalizes a technology that remains speculative at large scale. Some worry that this effectively hides the various social, cultural, and ethical concerns that would need to go into the assessment of CDR approaches as a viable form of climate action. Questions concerning land use, in particular, remain unresolved.

II.3. Typology of climate engineering technologies in context

40. By now, a variety of approaches is discussed under the umbrella term of climate engineering. In this section, we introduce some of the most important measures.

41. *Carbon dioxide removal (CDR) methods* include the following approaches:

   a. Direct air capture (DAC)

   b. Land-use management to enhance land carbon sinks, including for example afforestation/reforestation and peatland restoration.

   c. Sequestering CO_2 produced by biomass, which may also be used as an energy source.

   d. Increasing the uptake of CO_2 by the ocean (for example by 'fertilization' with naturally scarce nutrients or by increasing upwelling processes).

   e. Enhancing natural weathering processes which remove CO_2 from the atmosphere.

42. CDR approaches seem more viable, and in some cases acceptable, when they rely mostly on mimicking and strengthening the natural processes like afforestation and enriching the phytoplankton in oceans, which can act as major carbon sinks (Preston, 2013; Proelss & Steenkamp, 2023). For example, ocean fertilization involves stimulating phytoplankton to enhance their capacity for carbon sequestration. Previously, engineered nanoparticles, at concentrations non-toxic to aquatic life, have given rise to positive outcomes (Babakhani et al., 2022). Another approach, which is referred to as artificial ocean upwelling/downwelling, includes the pumping of nutrient-rich deep ocean water to the surface to promote phytoplankton growth, thereby enhancing CO_2 capture. The efficacy and feasibility of direct CO_2 capture, storage and utilization is also considered from the points of view of the atmosphere and industries releasing excessive CO_2 into the environment (Proelss & Steenkamp, 2023).

43. *Solar radiation modification (SRM) techniques* include the following approaches:

   a. Increasing the surface reflectivity of the planet (for example by painting structures with reflective paints, or planting crops with high reflectivity).

   b. Enhancing the reflectivity of marine clouds to reduce the amount of solar energy reaching the surface.

   c. Cirrus cloud thinning, which would work by removing infra-red-absorbing clouds from the atmosphere, thus reducing trapped heat.

   d. Injecting aerosols into the lower stratosphere to mimic the cooling effect of volcanic eruptions.

e. Reducing the solar radiation reaching the Earth by placing reflectors or shields in space.

44. SRM methods are aimed at modifying the Earth's radiation balance in an attempt to 'compensate' for the increased heating caused by higher greenhouse gas concentrations. In contrast to most (if not all) of the CDR methods, some of the SRM methods could take effect quickly – which could be an advantage when trying to prevent an imminent runaway temperature rise.

II.4. Technical, ethical, and risk dimensions

45. Though SRM and CDR both may have the potential to halt and reverse global warming, there are major differences in their intended modes of action, and in their ethical implications, which will be discussed later in the report. These major differences include:

a. The time scales over which they might work.

b. The possibility of reversal.

c. The degree of sensitivity to which they might be 'tuned'.

d. The spatial regimes of their potential effects (locally limited or global).

e. Their possible effects on natural processes.

f. Possibly unknown consequences.

46. For example, CDR methods such as direct air capture (DAC) and enhancing carbon sinks by tree planting or peat restoration act very slowly. In contrast, some SRM techniques may act quickly, and hence might be considered favourably in a situation in which the climate has reached an existential crisis point.

47. In general, CDR methods are in principle reversible, though the effects of reversing will be seen only over long timescales. However, a technique such as ocean fertilization is probably difficult to reverse, a characteristic shared by some of the SRM methods proposed.

48. Those methods that operate over longer time scales in principle have high sensitivity, perhaps largely because they can be stopped in their tracks – although the inherently long timescales mean that returning to a previous state will take time. Also related to sensitivity, SRM techniques have a particular challenge in that (a) the fraction of incoming solar radiation to be blocked is very small, and (b) our understanding of the delicate balance between increased greenhouse gas concentrations and reduced solar radiation is imperfect. It will be a real challenge to tune the method precisely enough to prevent overshoot leading to excessive cooling.

49. Other potential consequences that need to be considered in the case of some CDR approaches include negative impacts on terrestrial biodiversity by, for example, inappropriate tree planting, and the effects on marine biodiversity from ocean fertilization. With respect to CO_2 sequestration, the buried CO_2 needs to be stored permanently over hundreds of years – the consequences of a rapid release from underground reservoirs would be serious[3]. Furthermore, many physical consequences of reducing incoming solar radiation by stratospheric aerosol injection are not fully understood yet.

3 Two carbon storage projects have reportedly faced problems which could have caused CO2 to leak. See https://www.heraldscotland.com/news/23703174.pioneering-co2-storage-projects-may-leaked/

50. In addition, it will be important to consider not only the degree to which SRM and CDR methods may act on natural systems (land, ocean, atmosphere), but also the extent of uncertainty in our ability to predict the degree and effect of those perturbations. Ideally, any disruption should be minimal, but whichever methods are used to remove CO_2 from the atmosphere, we need to consider where that gas is removed to and how that 'final' location – whether combined with other material or hidden in underground reservoirs – may itself suffer potential negative consequences. The social feasibility and ecological sustainability of using these techniques also need to be assessed seriously.

51. Moreover, there are potential environmental consequences of SRM techniques relating to atmospheric circulation, the ozone layer, health-related impacts (on both humans and the natural environment), rainfall and ocean currents which could have regionally variable impacts which need careful research, and consideration of aspects such as equity, accountability, intergenerational justice, and the protection of legal and human rights.

52. In general, in assessing the ethical implications of climate modification, whether CDR or SRM, we need to take very seriously the uncertainties in assessing their impact and the need for more research. It is a shared belief amongst many scientists that 'natural systems' are more fine-tuned and complex than we may have previously thought – for example, experience has demonstrated that even the best laid plans (e.g., pest control by importing non-native predators) often backfire. And once we start to try to modify the climate deliberately, that backfire could be catastrophic.

II.5. The overshoot scenario

53. As seen above, the Sixth Assessment Report of IPCC (AR6) highlighted the differences between SRM and CDR, and proposed classifying CDR among mitigation actions, while leaving SRM approaches in the more controversial area of climate engineering. Yet, some scientists have suggested that SRM might also become necessary in order to attain climate policy targets of 1.5 °C or 2 °C (e.g., Irvine et al., 2019). Specifically, these scientists have argued that SRM might become necessary in so-called "overshoot" or "peak-shaving" scenarios.

54. These scenarios assume that global warming might temporarily exceed the temperature targets of 1.5° or 2°C before eventually returning to this target based on the large-scale deployment of CDR measures. In order to prevent dangerous warming levels, SRM is deployed in these scenarios to "shave the peak" off this excess warming and compensate for delayed mitigation. It thus serves to "buy time" in attaining the necessary emissions reductions (Long, 2017; MacMartin et al., 2018).

55. Temporarily overshooting the climate targets of 1.5-2°C could increase the tipping risk of several Earth system elements. Limited deployment of SRM could be considered to limit climate change while ambitious programs of mitigation and CDR are scaled up. There are scientific arguments based on available scientific knowledge that indicate that SRM is the only known approach that could be used to cool the Earth within a few years (United Nations Environment Programme, 2023). **Figure 1** displays how the four primary responses to climate change – emissions reduction, CDR, SRM, and adaptation in comparison to no emission policies (i.e., few or no steps are taken to limit greenhouse gas emissions) - could complementarily reduce impacts on humans and the environment.

56. Some experts have criticized such peak-shaving scenarios as a way of "escalating climate debt" (Asayama & Hulme, 2019; Asayama et al., 2021). These authors are primarily concerned that such scenarios work to mask, rather than erase excess warming and therefore foster an increasing dependence on the effective future deployment of large-scale CDR capacities, which do not exist at present.

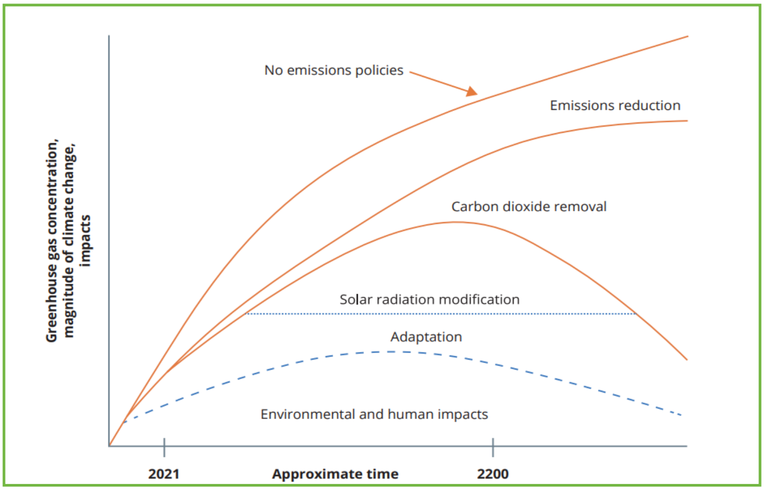

Figure 1. Potential complementary responses to climate change: greenhouse gas emissions reduction, carbon dioxide removal, solar geoengineering, and adaptation in comparison to no emission policies. This graph was originally called the "napkin diagram" in Long & Shepherd (2014) (Reproduced from Reynolds, 2022).

III.

ETHICAL ISSUES AND CHALLENGES

III.1. State-of-the-art of climate engineering ethical discussions

57. Ethical discussions of climate engineering are interdisciplinary, and so cannot be restricted to climate science or even to traditional philosophical discussions within the climate ethics literature (Pamplany et al., 2020). The fundamental reason for this is crucial to understanding the central ethical issues of deploying climate engineering approaches: they are not just purely normative discussions, but intrinsically political and economic, which pose difficulties in evaluating qualitatively different risks and benefits. Both risks and benefits of alternative actions as regards climate engineering need to be estimated, which means that there are numerous uncertainties involved in their description, as well as in the crucial comparative analysis.

58. One of the most prominent arguments for climate engineering is based on two combined assessments. The first is to regard climate engineering as providing a promising potential means for effectively dealing with our current climate crisis; the second is that current international efforts to reduce the production of greenhouse gases are unlikely to attain the Paris Agreement temperature targets (see Section II.1). Without feasible options to tackle the climate crisis, it could be thought reasonable to explore/assess climate engineering tools.

59. Another argument for exploring climate engineering options is to defend the moral justifiability of doing 'lesser evil'. One might add a related assessment that as there would be an opportunity cost for not adopting climate engineering, we should compare the cost of the risks that climate engineering poses with the cost of not exploring climate engineering. The result of this comparison is unsurprisingly not unanimous, and unlikely to be resolved in the near future, as there are several factual uncertainties involved in each moral judgement.

60. Similar disagreement about the likely moral consequences of climate engineering concerns how we evaluate the moral status of the 'technological fix'. Suppose climate engineering measures, at least some less risky approaches, are successfully implemented. Some critics would readily point out that success itself produces morally undesirable consequences to the effect that we do not need to take our ecological responsibility seriously, as a much easier way to deal with the climate crisis is available (Reynolds, 2015). This relates to the moral hazard argument explained below. On the other hand, one might argue that successful climate engineering would prompt greater awareness among people to take a more rational attitude towards climate change (Resnik & Vallero, 2011). Again, there are uncertainties about which moral consequences are the most likely to be obtained when relatively safe climate engineering is used. Apart from this disagreement, another argument for climate engineering is that it may give us more time to implement a more ethically acceptable way to deal with the climate crisis, even when climate engineering itself does not offer a morally acceptable ultimate solution (Neuber & Ott, 2020).

61. There is no controversy concerning the fact that climate engineering involves risks. Still, we need to distinguish different types and levels of risks within climate engineering. It is generally accepted that SRM poses much more serious risks than other methods, especially when compared with CDR. One of the prominent arguments against climate engineering is that the risks are epistemologically too complex and large to be morally acceptable. In order to be effective in tackling the current climate crisis, climate engineering would need to be applied globally, but thus far only small-scale experiments have been carried out in order to try to show its feasibility (Irvine et al., 2016). Apart from the scale-up problem, there is a gap between science and engineering. Scientific results obtained in a laboratory environment need to be translated into the real environment. This can pose intrinsic difficulties in evaluating the 'real' effectiveness of proposed engineering solutions. For instance, as discussed above, it is difficult to estimate unintended side effects of their implementation (Keller et al., 2014).

62. One might argue that we need more scientific research and real-world testing of climate engineering techniques in order to reduce these epistemic uncertainties and base our policy decision on sounder evidence. However, it could still be regarded as an ethically unacceptable position to even try out, say, a moderately scaled-up SRM if we have reason to believe that the uncertainties are too great for us to anticipate its large-scale, long-term unintended consequences. The moral argument for/against scientific and engineering research is thus closely related to our evaluation of current climate knowledge (Gardiner, 2017).

63. Many critics of climate engineering have raised several justice issues, including intergenerational, distributive, procedural, food and regional justice (Gupta, 2018; Preston, 2013; Svoboda, 2016; McLaren, 2016; Dékány, 2018; Hourdequin, 2018). The unintended (and in many cases unpredictable) unequal impact of SRM often lies at the heart of these criticisms of justice considerations. Even when human beings as a whole would benefit from the successful deployment of SRM, it would be practically impossible to distribute risks and undesirable side effects equally across different regions of the world. Furthermore, there would be an enormous procedural problem to tackle as we would need to have ethical consensus over proper recognition of, and if necessary, compensation for the unintended consequences of SRM. It would thus be more difficult to satisfy more stringent justice principles with regard to climate engineering.

64. Even if the scientific and engineering feasibility of climate engineering, despite its epistemic uncertainties, is admitted, we could still doubt its political feasibility on the grounds that the governance challenge of climate engineering on a global scale is complex enough to be comparable with current imperfect governance relating to the unfulfilled emissions target (Ackerman, 2015; Blackstock & Low, 2019; ETC Group, 2010; Cox et al., 2018). Who should have the moral authority to engage in global-scale climate engineering while respecting national sovereignty and deliberative democratic processes? Although the challenge is not unique to climate engineering, the need for global, highly coordinated action within a short time makes the governance challenge for climate engineering greater.

65. The difficulty of the governance challenge itself does not make climate engineering unacceptable. Still, if one judges the difficulty of properly managing the justice issue mentioned one might think that it would be ethical to look for equally efficient, but politically more feasible options. Whether such options are available is controversial.

III.2. Key arguments in the debate about climate engineering

III.2.1. The slippery slope argument

66. A concern about climate engineering research, especially about SRM, is that it could create a 'slippery slope' - facilitating acceleration towards eventual deployment: research is at the top of a slippery slope, at the bottom of which awaits the full-scale deployment of potentially risky technologies. Some of the ways in which this acceleration scenario could occur are (NASEM, 2021):

   a. Research programmes could create political momentum towards deployment.

   b. Research programmes could create sociotechnical communities of interest, motivating further development of the technology.

   c. Those developing the technology will seek an opportunity to monetize it, thus motivating a push for deployment.

67. There are also countervailing scenarios in which technologies are not deployed or in which governance could effectively mitigate acceleration (NASEM, 2021):

   a. Research could discourage deployment if it is found that it is very difficult to produce a climate engineering technology that is an 'easy' alternative to greenhouse gases mitigation.

   b. It may attract less political support if it takes a long time to detect whether a climate engineering intervention is working.

   c. There is a reluctance to advocate for deployment in the face of uncertainties about climate engineering risks.

   d. The economic acceleration scenario (NASEM, 2021) is mitigated by substantial economic forces pursuing more traditional climate mitigation measures.

68. Climate research is extensively governed through existing regulatory requirements, funding conditions, and peer review. However, climate engineering research requires additional governance provisions because of its indirect, socio-politically mediated risks. Research governance can enable, legitimize, and control research by enforcing principles under which research plans should be disclosed and implemented, and whose results should be openly published.

69. Hubert (2021) discusses the options of the development of a flexible, near-term code of conduct for climate engineering research. This can be particularly useful at the early stages of governance, where problems and solutions are uncertain. The proposed Ethical

Framework for Responsible Climate Intervention Research is built on the premise that the process of developing climate engineering research governance must involve awareness, discussion, and engagement of a variety of experts representing a full range of disciplines, government and intergovernmental representatives, civil society, and the lay public.

III.2.2. The moral hazard argument

70. Moral hazard concerns relate to situations in which there is a lack of urgency to act in the face of risk on the part of some persons who are not directly impacted by the risk at issue. Although the two climate engineering strategies considered in this report are radically different (see above under Section II), they share the same 'moral hazard' - that the use of CDR and/or SRM and its resultant potential cooling effect could provide stakeholders with an excuse to slow the pace of reducing carbon dioxide emissions or to continue using fossil fuels at current or even accelerated rates (Lawrence & Crutzen, 2017).

71. There are concerns that aggressive research into climate engineering approaches would reduce the impetus and support for existing climate change mitigation policies and approaches. Such a moral hazard in climate engineering can prevail at different tiers: for example, at a personal level, individual voluntary efforts aimed at mitigating climate change could be reduced. Climate engineering can be perceived to lead to a 'rebound' — the pursuance of reckless approaches, irresponsible behaviours, and the continuation of carbon-intensive lifestyles that could amplify the risks linked to the embrace of climate engineering technologies (Corner & Pidgeon, 2014).

72. Social acceptability of funding climate engineering research may be related to how moral hazard concerns are addressed. A novel approach argues for the importance of moving beyond the moral hazard framework - shifting the focus away from evaluating the potential risks and benefits of specific interventions such as CDR or SRM, and towards more comprehensive assessment of the costs and benefits. This supports a more general perspective on the available policy options where mitigation, adaptation, and technological goals can be evaluated at the same time, thus minimizing concerns about moral hazard effects (Jebari et al., 2021). Consequently, a research program on any of these climate intervention strategies can be expected to have greater social acceptability if it is embedded within a portfolio of climate policies and research that includes adaptation strategies and a strong commitment to reduce carbon emissions.

III.2.3. Organized irresponsibility

73. The discussion of doing vs. not doing (see Section V.3.) should also consider the possibility of "organized irresponsibility". For Ulrich Beck, who developed this concept, responsibility for the creation and resolution of environmental risks belongs to several institutions and systems (governments, industries, experts, and legal systems, etc.), but, at the same time, no institution seems to be specifically responsible. This paradoxical circumstance arises because global environmental risks are full of uncertainties and synergistic effects and have complex causal chains and long-term periods of latency. Therefore, assigning responsibility and blame for harmful consequences is extremely difficult, if not impossible.

74. The systemic interdependence of all the institutions and systems involved begets a general complicity, in which there are no single causes or responsibilities (Beck, 1992). It is a "labyrinth" of "simultaneous liability and unaccountability" (Beck, 2002). The organizations responsible for safeguarding the higher interests of the community, for its security and protection, are confronted with the increasing difficulty of establishing proof, attributions, and compensations.

III.3. Economic challenges

75. Climate change is a typical example of a many hands problem because it is a phenomenon that is very complex, in which a large number of individuals are causally involved, but in which the role of individuals in isolation is rather small (Poel et al., 2011). Within this broad spectrum, economic challenges are also at stake. The close association between the problem of climate change and economic growth has driven new approaches such as "green growth", "green economy" or "green transition", which tend to emphasize the economic benefits of environmental protection and the possible synergies between environmental protection and economic growth (Gunderson et al., 2018). Among the threats posed by climate change, companies are particularly concerned about the increase of regulations for fossil fuels and the cascading effects thereof on production chains (Buck, 2012). Schemes designed for deliberate intervention to mitigate global warming, like climate engineering, are pushed by corporations as a favoured response to tackling global warming, representing a way to address the issue while fostering business investments and economic growth (Gunderson et al., 2018).

76. The climate has already made its way into the domain of financial markets and stock exchanges. For example, the system of international carbon trading, a market for buying and selling carbon dioxide emission licenses; or the panoply of tools of climate insurance, such as "weather derivatives", "environmental mortgages", or "catastrophe bonds". The ethical dilemma here is whether there ought to be markets for environmental goods (Neuteleers, 2022). Positions often fall into two polarized arguments regarding the commodification of nature (Neuteleers, 2022): one contends that environmental goods should not be subject to market forces, deeming it unethical to trade nature (e.g. Sagoff, 2004; Sandel, 2013); another assumes that markets can serve as an important mechanism for addressing environmental problems, especially when these problems result from market failures (e.g. Stern, 2007).

77. Climate engineering is an impactful large-scale approach that goes directly from computer modelling to full-scale planet-wide implementation. While computer models have displayed a remarkable predictive ability, they are not infallible and may underestimate some risks and overstate others (e.g., Hegerl & Solomon, 2009). Risks are greater because the efforts to launch climate engineering technologies also require international cooperation and coordination among multiple countries with different economic interests. The challenge might be to tailor climate engineering technologies to help the world's most vulnerable countries while, at the same time, taking care not to expose others to greater risks of extreme weather events (Klein, 2014). Climate engineering will reshape the geopolitical landscape of climate change, and this implies greater political engagement (Blackstock, 2012).

IV.
ETHICS OF CLIMATE ENGINEERING RESEARCH

79. Scientific research on climate engineering plays a particularly important and at the same time highly complex role. The questions at stake are not just technical ones. As we have seen in previous sections of this report, climate engineering is deeply imbued with profound ethical, social, and political considerations. This is primarily because the decisions in this domain have the potential to affect societies and ecosystems around the globe, encompassing everything from local habitats to worldwide weather patterns. In addition, most of the proposed interventions are associated with various risks, uncertainties, and unknowns, which makes it even more difficult to make informed decisions, especially in the field of operational deployment.

80. When considering the ethics of climate engineering research, we therefore need to take into account the many dimensions of the complex interplay between scientific knowledge, public dialogue and decision-making. With this in mind, this section begins by providing a brief categorization of the kinds of research that are currently discussed in the case of climate engineering. Building on this categorization, the focus is on four dimensions shaping the interaction between scientific knowledge and decision-making: the first concerns the value of the freedom of scientific research and its implications for the case of climate engineering (IV.1), the second concerns the values of responsibility and inclusiveness in the case of climate engineering research (IV.2), the third reflects on the role of public institutions in ensuring the broader social interest and preserving fundamental moral values (IV.3); the fourth addresses the crucial role of media and public communication in the context of climate engineering research (IV.4). In the fifth and final part of this section, the importance of climate data collection is highlighted by turning to a practical example, namely integrated sensing and communication (ISAC) technology (IV.5).

81. To properly address the various dimensions defining the ethics of climate engineering research, we first need to consider the very heterogeneous and fragmented research landscape of climate engineering. Research on carbon removal technologies, on the one hand, has been around for a long time, not only in the context of so-called integrated assessment models, but also in the form of early outdoor experimentation exploring, for example, ocean fertilization approaches. Particularly in the past decade, research in this field has vastly proliferated and now includes 'theoretical' modelling studies and social scientific research which addresses the potential opportunities and risks of relying on carbon removal technologies (see Carton et al. 2020 for an overview), as well as several pilot-stage projects. This development has been driven, as we have seen in previous sections of this report, by the incorporation of CDR into the modelled emissions pathways by various nation states, as well as in the scenarios assessed by the IPCC reports.

82. With regard to SRM research, the distinction between indoor and outdoor research remains crucial: there are indoor SRM research investigations, small-scale outdoor SRM experiments, and potential large-scale SRM deployments. Indoor SRM research investigations involve theoretical analysis, social science research, computer simulations and laboratory experimentation. Small-scale outdoor experimentation refers to the emission of limited quantities of material over a short period of time to examine critical and poorly understood SRM-related processes in the real atmosphere with negligible climatic impact. Large-scale SRM deployments would likely be of planetary scale, and would need to continue to be implemented for decades or more to be effective.

IV.1. Freedom of scientific research in climate engineering

83. One important aspect to consider when reflecting on the ethics of climate engineering research is the freedom of scientific research, which is one of the human rights explicitly recognized by the Universal Declaration of Human Rights since 1948 (Art. 27) and later reaffirmed and specified in the International Covenant on Economic, Social and Cultural Rights (1966, Art. 15). These documents are at the basis of the international tradition that considers scientific knowledge a value per se and freedom of scientific research a fundamental principle and guide for action. In the field of climate action and climate engineering, this means that all options and proposals should be based on scientific evidence and data (see IV.5 Climate Data Collection).

84. Some documents in the field of climate action and climate engineering have foregrounded the freedom of scientific research and the value of scientific research. In May 2021, the Royal Society, together with the world's leading scientific academies, for example, issued a statement on the need to accelerate action on climate change. The statement recommended that "every government should develop an evidence-based roadmap setting out the technologies that it requires to achieve the goal of reducing greenhouse gas (GHG) emissions to net zero, given its own circumstances. We encourage all countries to deploy technologies and nature-based solutions which are available now, and to invest in research and innovation to address the outstanding challenges" (2021a). This statement by the Royal Society highlights the need to develop a better scientific understanding of the climate, with a particular emphasis on the need for better modelling technology.

85. The main goal of any research program on climate engineering should be to better identify and reduce the scientific and societal uncertainties over the efficacy, benefits and risks of the different technologies relating to global warming in the absence of climate engineering. As a matter of fact, scientific knowledge regarding CDR and SRM is fragmented, with substantial gaps and uncertainties in many areas. It is necessary to build research capacity to increase the community of experts and to integrate that community into the policy-making process.

86. Science can contribute to the reduction of uncertainties, although there are limits to the level of reduction that can be expected, as particular uncertainties can be expanded or new uncertainties can appear as indirect effects, socioeconomic and political/institutional responses over multi-decadal timescales, and attribution for climate- and weather-related extremes (NASEM, 2021).

87. A significant source of uncertainty is that climate engineering deployment would not occur in isolation, so its benefits and risks would depend on a variety of other factors: the goals of the deployment, the background emissions pathway and adaptation plans being followed, the sustainable development goals pursued, and the established governance framework.

88. A key consideration to help inform future decision-makers deciding whether to pursue climate engineering techniques to counter global warming should be a comparison between the extent of climate risk that the technologies are able to reduce and the severity of any countervailing risks that they may engender. Risks of climate engineering deployment may arise from both interactions with the climate, and their potential to exacerbate existing risks and/or introduce new biological and societal risks (Felgenhauer et al. 2022).

89. In addition, the inter-dependence of scientific expertise and political decision-making needs to be taken into account when reflecting on the ethics of climate engineering research. A rich body of scholarship from the field of science studies has demonstrated that scientific expertise does not linearly translate into policy advice. Instead, decision-makers usually find themselves in a situation where there is evidence and counterevidence for a range of different and even conflicting policy proposals. Different kinds of scientific expertise serve to articulate different kinds of policy proposals; different forms of evidence highlight different sets of concerns or challenges. Particularly in the case of contested issues such as climate action, scientific expertise might even tend to *fuel* controversy rather than reduce it (see Sarewitz, 2004). This is not necessarily a problem, but it needs to be taken into account in order to foster productive engagement with, and governance of climate engineering research. The field of responsible research and innovation (RRI), which we will turn to in the next section (IV.2), seeks to do precisely this.

IV.2. Responsible research and innovation in climate engineering

90. The concept of responsible research and innovation (RRI) draws on the combined recognition of (a) the powerful role that science and innovation play in shaping contemporary societies, and (b) the complex ethical challenges involved in emerging fields of research, such as climate engineering, synthetic biology, or genetically modified organisms (Owen et al., 2012, 751-752). RRI has gained significant policy relevance in the context of the European Commission's Horizon 2020 programme. The concept has been mobilized to foster a different understanding of the role of science in society. Specifically, the goal has been to "herald […] a transformation from science in society to '*science for society, with society*' (Laroche, 2011, quoted in Owen et al., 2012, 753, emphasis added). RRI, in this sense strives, towards providing a science and innovation framework which represents and caters to shared societal values.

91. This means that RRI is, first of all, "concerned with *the purpose* of science and innovation" (Owen et al., 2012, 754, emphasis added). It seeks to go beyond managing unintended risks and instead focus on the positive contribution of science and innovation – "what we want it to do" (Owen et al., 2012, 754). Secondly, and building on this, RRI seeks to advance "mechanisms of reflection, anticipation, and inclusive deliberation" in the context of research and innovation (Owen et al., 2012, 755). It seeks to involve different groups of societal stakeholders more actively and effectively in the processes of research, innovation, and development in order to ensure that science and innovation does indeed respond to concrete societal concerns. Thirdly, and finally, RRI draws on a collective notion of responsibility which extends not only to scientists, but also to science policy and funding agencies.

92. As suggested earlier, the case of climate engineering research has been formative for RRI literature. This literature has drawn attention in particular to two challenges which climate engineering research and governance are facing.

93. The first issue concerns the focus on technical aspects in climate engineering assessments (Low & Buck, 2020, Owen, 2014, Morrow, 2017, Gupta & Möller, 2018, Foley et al., 2018). RRI authors have voiced the criticism that many assessments of climate engineering tend to foreground natural scientific and technical questions and concerns surrounding climate engineering. As a result, these assessments highlight metrics of physical risk and technical feasibility, rather than exploring ethical and societal concerns. In an effort to respond to these concerns, some climate engineering assessments have begun explicitly to incorporate RRI elements into their assessment procedure (see, e.g., Long et al., 2012; Chhetri et al., 2018). Rather than treating ethical and societal concerns as separate or secondary to concerns of physical risk, these reports have sought to place greater emphasis on "anticipatory governance" approaches. Such anticipatory governance approaches seek to involve different stakeholders early on in the innovation process in a bid to anticipate relevant societal questions.

94. In order to advance such attempts at anticipatory governance in the field of climate engineering, RRI scholars have come up with principles which might guide climate engineering research and development. The most prominent set of principles in this context is the so-called Oxford Principles (Rayner et al., 2013)[4].

95. The strong emphasis on stakeholder engagement points to a second challenge that RRI scholars have emphasized with respect to climate engineering. This second challenge concerns the question of how to properly engage the public in this debate and who this 'public' is precisely. A 'first wave' of engagement efforts constructed the issue of climate engineering rather narrowly and left little room for open-ended deliberation and true engagement with the objections, questions and hopes that the engaged public brought to the table (Flegal et al., 2019). Instead of providing a platform for symmetrical exchange, these first rounds of engagement were set up asymmetrically, as a kind of training exercise in which experts informed the lay public on an emerging technology.

96. A second round of engagement efforts sought to change this. Bellamy and Lezaun (2017), for example, highlight the relevance of contextualizing the prospect of climate engineering in the broader context of climate action in order to achieve a productive and symmetrical exchange. Rather than isolating climate engineering measures as a dire measure of last resort against urgent climate change, the authors suggest engagement efforts are more productive when placing the proposed measures in the larger context of other measures of mitigation and adaptation. Such a contextualized setting of the debate allows the public to ask broader questions regarding the kind of response measure that climate engineering would be, and to voice their hopes and fears more freely. The challenge that these efforts illustrate is an inherent tension between informing and forming the public for climate engineering (Low & Buck, 2020): In the context of highly technical debates, engagement always includes an "informing" dimension, in which the public learns information about novel technological concepts. At the same time, however, engagement needs to leave room for the involved participants to make up their own minds and articulate their individual concerns, which is particularly difficult to ensure when the debate is highly controversial.

4 These principles were developed by a group of scholars in 2009 and endorsed by the United Kingdom government in one of the very first official national-level policy statements on climate engineering. It also informed the following Asilomar Conference on Climate Intervention Technologies in 2010.

IV.3. The role of public institutions in climate engineering research

97. One of the central challenges facing the debate over climate engineering research is that ethical debates on emerging technologies rarely lead to global governance actions. The three main reasons are: (1) Science, by nature, is highly distributed. Much of it is done in research labs, spread around the globe, under various local regulation schemes. The effectiveness of global governance actions is therefore usually limited. (2) In many cases, by the time ethical concerns are raised, it is too late to control the research or its deployment. Traditionally, basic research is done with no limitations, and its results are published. While the use of the results can possibly be regulated, in general, once the results are published, it is too late to control their use. (3) Global governance actions require appropriate tools and multinational agreements. Because of different national cultures and interests, such agreements can rarely be achieved. As such, there are very few examples where ethical considerations were globally discussed and agreed upon to provide guidance for scientific research.

98. One such example is the prohibition of human reproductive cloning. Reproductive cloning of a human being is widely viewed as a violation of human dignity, and the Universal Declaration on the Human Genome and Human Rights, adopted by UNESCO in 1997 (UNESCO, 1997), stands as a significant milestone, explicitly mentioning the prohibition of such practices. It is worth noting that this declaration was adopted in the same year, shortly after the birth of Dolly the Sheep, the world's first cloned mammal, was announced. The unexpected speed of cloning technology development and the widespread awareness of our unpreparedness for the potentially disastrous consequences of the technology were arguably behind this prompt response.

99. A further example where international agreement has been reached on restricting the deployment of new technologies are the conventions on the use of biological (Biological Weapons Convention, United Nations, 1972) and chemical (Chemical Weapons Convention, United Nations, 1993) weapons, agreements which were driven in significant part by ethical arguments from concerned scientists. Again, it was crucial for the emergence of this global governance that the scale of the potential disasters and human suffering from biological and chemical weapons was enormous, and that despite its urgency there were no globally effective countermeasures.

100. The ethical debate on climate engineering has raised the question of whether global governance actions are also called for. Because of the large scale of this technology, and its dependency on significant funding by public institutions or large private companies, meaningful regulation is necessary. UNESCO is the natural leader of a debate on the need for global governance of climate engineering, and its implementation.

IV.4. The role of the media and public communication in climate engineering research

101. A fourth facet to consider when addressing the ethics of climate engineering research is the powerful role that the media play in shaping attitudes towards emerging technologies. The media provide a lens through which most of the general public understand and form opinions on such emerging technologies. The narratives and views disseminated by the media can have a significant impact on the tone, direction and depth of the public conversation about the challenges and opportunities presented by climate engineering.

102. The media represent a crucial bridge which connects the world of scientific research with the everyday experiences of the general public. When the media perform their role effectively, they not only educate but also inspire, catering to a key tenet of RRI (see Section IV.2). They have the ability to translate abstract scientific concepts into real-world implications, allowing the public not only to appreciate but also to actively engage with the significance of scientific research and innovation. However, the very platforms that can amplify the achievements of science can also propagate inaccuracies or misrepresentations. Such distortions can obscure information, making it harder for the public to distinguish fact from fiction or to appreciate the nuances and complexities inherent in scientific exploration.

103. The dynamics of the digital age, where engagement metrics such as views and clicks dominate, can sometimes skew the media's approach. Controversial or provocative topics naturally draw more attention, potentially tempting outlets to be inclined towards sensationalist reporting or to magnify internal debates and disagreements within the scientific community.

104. Information — or in some cases, misinformation — can proliferate at lightning speed across digital platforms. This rapid dissemination, when coupled with algorithmically driven content curation, can result in the formation of echo chambers. These are digital bubbles where individuals are repeatedly exposed to content that merely echoes and amplifies their pre-existing beliefs and views, potentially excluding diverse perspectives and a broader understanding of issues. Such environments underscore the imperative for heightened media literacy in order to ensure a well-informed and discerning public.

105. The task of science communication goes beyond simply disseminating data or stating facts. Its true mission is to capture the prevailing state of knowledge, reflecting all its complexities, challenges, and unresolved issues as experienced by the scientific community at any given time, and engage the public in the process of research and innovation. The defining characteristic of science is that it evolves. It thrives on constant exploration, discovery and falsification. Therefore, effective science communication does not merely communicate the results of research, but sheds light on the process of scientific research. In doing so, it fosters a more nuanced appreciation of science among the public, setting realistic expectations and promoting informed discussions.

106. The world of scientific research is often one of probability rather than certainty. This characteristic requires caution in science communication, emphasizing the importance of acknowledging these uncertainties. It is crucial to understand and communicate to the public that the presence of uncertainty doesn't detract from the merit of a scientific discovery; instead, it provides a contextual lens through which the finding needs to be viewed. While scientists are trained to work within the boundaries of probability and uncertainty, politics and the general public often seek clear answers and reassurances. This difference in views requires a thoughtful approach to communication, ensuring that technological advances are presented with both the potential benefits and the challenges they bring, promoting a balanced understanding and informed debate among all stakeholders.

107. For most people, the concept of risk is strongly intertwined with personal feelings and intuitive reactions. Contemplating interventions in our planet's complex climate system, even when motivated by the noblest of motives, can be deeply worrying. Such feelings of apprehension are frequently amplified by certain sensationalist media presentations. Instead of offering a comprehensive understanding, these portrayals often zoom in on the most catastrophic possibilities, neglecting to provide context about the range of potential outcomes and the probabilities associated with them.

108. In contrast, within the scientific community, risk assessment is a meticulous and structured evaluation. It entails a comprehensive review of all available data, where the potential upsides of a course of action are set against its possible drawbacks.

109. For a significant part of the world's population, the idea of humans taking on an almost divine role by manipulating the climate inspires a deep sense of anxiety and fear. Such sentiments, while rooted in genuine concern, arise from the understanding that the ripple effects of any unintended consequences could reverberate on a worldwide scale, affecting ecosystems, economies, and communities alike. Regrettably, the mainstream narrative, often influenced by attention-grabbing headlines, leans heavily towards this sense of impending doom, frequently sidelining any discussion of the potential advantages or the strides made in technology and methodology that serve to mitigate these risks.

110. An informed public participating in an open debate can act as an additional safeguard against potential bias that the internal scientific system may fail to identify and remove. By questioning methodologies, data sources and explanations, public debates can reveal conflicts of interest or biases that would otherwise remain hidden and unrecognized, even within the scientific community. This underlines the importance of ensuring that scientific findings are not only accessible, but also comprehensible to the general public.

111. The relationship between the scientific community and the public is therefore symbiotic. Scientists have a responsibility to produce and communicate impartial, accurate and reliable information, and the public has a responsibility to hold them to account. In the field of climate engineering, maintaining an open dialogue, fostering mutual respect and continuously seeking the truth are essential to securing our planet's future.

IV.5. Climate data collection

112. In the final part of this section, this report turns to a technical aspect, namely the importance of data collection in the context of climate action in general and climate engineering in particular. From the ethical point of view, the ability to collect climate data with high tempo-spatial resolution, even in real time, almost everywhere on earth, can be beneficial for: (1) fair distribution of resources and ensuring that improving climate in one region does not affect climate negatively in another region; (2) early warning of climate-related disasters; and (3) close monitoring of the desired or undesired effects of certain climate engineering technologies. Moreover, integrated sensing and communication (ISAC) technology can do that in a sustainable way since it is built on efficient use of resources.

113. Existing technologies for collecting climate data are based either on remote sensing (satellites and weather radar) or, sometimes, on very sparse localized measurements (weather stations). To be able to make informed decisions regarding various climate engineering technologies, accurate, high-resolution data collection - especially regarding the effect of climate on humans, i.e., near ground – is required.

114. As human made electromagnetic waves, mostly used for wireless communication, travel almost everywhere in the atmosphere, it has recently been proposed to use them for extracting climate data, using the emerging ISAC technology (Cui et al., 2021). ISAC has gained significant attention in both academic and industrial research. It has been applied to various applications, including vehicular networks, indoor positioning, covert communications, and more. ISAC is also recognized as an emerging technology for future wireless standards like 5.5G, and next-generation WLAN. In particular, the 6th generation of mobile communication (6G), it is envisaged that the function of sensing and communication will coexist and be fully integrated in a single system, sharing the same resources in time, frequency and space (Tan et al., 2021).

115. With ISAC technology, large-scale wireless networks (such as cellular networks) can assist in collecting climate data. Rainfall measurement, pollution monitoring, fog, snow, and sleet detection are potential applications that can be enabled by analysing the changes of the wireless propagation owing to atmospheric phenomena. As such, a cellular network with a sensing function serves as a built-in real-time monitoring facility, and can therefore be utilized as a widely distributed large-scale atmospheric observation network. Moreover, with the continuous exploitation of higher frequency, future urban cellular networks could also monitor locusts or other insects, serving as an insect observation network in urban areas (Wang et al., 2022). This is particularly relevant, considering that 5G networks support one million devices, which is envisaged to be further improved 10 times (to 10 million) per square kilometre in 6G networks (Jiang et al., 2021). It is expected that by 2030 there will be 5 billion 5G connections globally (GSMA, 2023), this gives us an idea of how many "environment sensors" we could have in the future.

116. It is important to point out that ISAC technology could complement other tools for sensing the environment, such as the Internet of Things (IoT). As indicated in the COMEST report entitled *The Ethical Implications of the Internet of Things*, IoT may have adopted different names, but it has always entailed "a world made up of a trillion connected and intelligent things, and the oceans of data they produce" resulting in computational power being infused into things not traditionally considered computers, which would be able to listen, see or feel, hence creating an environment where the physical and the virtual domains come together (COMEST, 2021).

V.
ETHICS OF CLIMATE ENGINEERING GOVERNANCE

V.1. Justice and human rights

117. A major concern that is raised by the climate engineering approaches is whether, in the light of the many scientific uncertainties and social issues involved, the intentional manipulation of the global climate should be allowed. This debate is not confined to any particular discipline, but rather requires a multisectoral discussion grounded in ethical, philosophical, political and scientific discourse, as discussed above (Pamplany et al., 2020).

V.2. Moral responsibility or moral impediment

118. One of the fundamental ethical dilemmas regarding climate engineering involves reconciling the concepts of moral responsibility versus moral impediments. Since the human species is primarily responsible for climate change, it is our responsibility to carry out all necessary climate actions, primarily mitigation and adaptation, but not excluding the possibility of climate engineering techniques. Climate engineering approaches should be considered, but taking into account the risk of irreversible damage to the planet that would be beyond our ability to repair.

119. The benefits and burdens ascribed to societies depend on the specific economic, political, and social framework of each society. However, these frameworks cannot be assumed to be stable, which means that the ascription of benefits and burdens cannot be guaranteed to be stable (Lamont & Favor, 2017).

120. Among climate engineering approaches, SRM, for example, has according to simulations the potential to bring benefits for some and risks for others, thus leading to both winners and losers. The unequal distribution of risks associated with climate engineering may raise moral issues that need to be addressed.

121. It is also clear from the discussion in Section I.2.3 that the way in which burdens and benefits are distributed in a particular society would directly impact the 'readiness status' of a society in terms of being able to effectively participate, navigate, or govern climate engineering technologies. The very fact that the frameworks that generate the distribution of benefits and burdens in a society are not static brings an additional layer of uncertainty to ethical evaluations of climate engineering technologies, as it renders determining who bears the cost of climate engineering even more complex (see the discussion on proportionality and risk assessment in Section I.2.3.).

V.2.1. Equity

122. Another concern is that climate engineering tools can also create greater polarization between the world's advantaged and less advantaged inhabitants (Roeser et al., 2020). Though SRM may potentially benefit some populations, on the other hand, it may also magnify the environmental risk to poorer countries and vulnerable people (Gardiner, 2011). Aerosol injections could lead to food insecurity, which would burden already negatively affected poorer and underprivileged regions (Preston, 2013). Moreover, climate engineering tools could be weaponized for territorial and political purposes. Historically, weather modification technologies like cloud seeding have been deployed for military purposes. Hence, the possibility of the potential for military or geopolitical use of climate engineering calls for strengthening global efforts for its governance (Nightingale & Cairns, 2014).

V.3. Issues of governance and regulation of climate engineering

123. The window for limiting warming to 1.5°C above pre-industrial levels is narrowing rapidly. Policies currently in place point to a 2.8°C temperature rise by the end of the century. Implementation of the current pledges will only reduce this to a 2.4-2.6°C temperature rise by the end of the century, for conditional and unconditional pledges respectively (UNEP, 2022). A recent report of the Climate Overshoot Commission (2023), which understands "climate overshoot" as crossing the 1.5 °C global warming threshold, stresses that CDR techniques should be developed and deployed to help achieve net-zero – and, ultimately, net-negative – emissions and highlights the need for an expansion of research in SRM pursuing international governance dialogues.

124. Action on climate change suffers from a gap between the global approach that action and policy would require and the current predominantly nation-State-based international legal order: there are problems with agreeing on which measures to take, problems with distributing burdens and benefits, and more.

125. International law has thus far been highly ineffective in climate change mitigation. The main reason is that international law is based on a consensus model. This means that it must be in the interest of each party (i.e., nation-State) to sign the agreement, otherwise there is no agreement (nothing is agreed until everything is agreed). Reaching such agreement is not easy in a field where the consequences may vary in both space and time. For example, the effects of an intervention do not necessarily occur in the same territory of the State taking initiative and bearing the costs, or even at the same time the initiative was taken.

126. In terms of official processes and legal instruments at the international level, some 11 principal multilateral agreements have been identified as potentially relevant for governance of large-scale CDR or SRM, including UNFCCC and its Paris Agreement, the Convention on Biological Diversity (CBD) and the London Convention and London Protocol on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (LC/LP) (Talberg, 2017). However, existing international laws are clearly not sufficient to deal with risks, uncertainties, and the ethics of climate engineering.

127. In fact, climate engineering technologies which are in the early stages of research involve substantial uncertainties and risks, and this raises ethical and governance dilemmas. The world is not yet ready to draw conclusions on SRM: whether it should or should not be researched or ever be used, and what international processes may be needed or able to reach such conclusions (Pasztor, 2022).

128. One of the reasons that makes climate engineering controversial is the shift from impact mitigation measures, essentially based on the idea of not doing something (i.e., avoiding those human activities that are most damaging to the environment, such as greenhouse gas emissions), to the idea of doing something that can alleviate the most severe effects of climate change. At first sight, doing something might be perceived as a heavier responsibility for whoever makes that decision (who should take responsibility for the failure of climate engineering measures or unforeseen negative side effects?), but according to the legal doctrine, there are circumstances in which not doing something can be equivalent to doing something. This is the case when a person or even a State has a legal duty to intervene, a duty to prevent an event, or a duty of care. In the climate action debate, this could be the case for adaptation measures, which although conceptually have no effect on the causes of climate change, can nevertheless reduce the impact on populations exposed to floods, droughts, or other catastrophic events.

129. In this light, the problem can be formulated as follows: do States, under international law, have the obligation to avoid the worsening of the global situation? For example, can a duty for States arise from human rights in relation to climate? The Paris Climate Agreement is not a good example. It is not legally binding, and the reaction to violation of the pledges of the States is highly ineffective, as the vast majority of countries are currently not meeting their promises. A deeper exploration of international law reveals a reality which might be described in a different way (Lamont & Favor, 2017).

130. Although it can be argued in logical and even legal terms that *not doing something* can be (under certain circumstances) equal to *doing something*, the problem of climate engineering has special aspects which can narrow the differences between the two types of "action". First, mitigating does not mean simply *not doing*, because it requires several very important things to be done (such as the reconversion of important economic and social activities, with all the associated costs); second, if the criterion is to do something that can avoid something dangerous, it becomes necessary to make distinctions in the field of climate engineering, to distinguish between the different techniques, and to assess the risks and benefits of each (see above, paragraph 23, Taebi et al., 2020).

131. Such an analysis will have implications for both CDR and SRM. CDR resembles emissions abatement, in which individual actors choose whether to take immediate and costly actions whose climatic benefits would be widely dispersed and delayed in time. In contrast, some SRM methods presently appear to be relatively inexpensive and rapidly acting, such that, even though their expected beneficial effects would still be widely dispersed, the benefits that would immediately accrue could outweigh their direct financial costs (Smith, 2020). These distinct problem structures mean that the implications of existing international law and the probable development of new law will vary, mainly between emissions abatement and CDR in one column and SRM in the other.

132. Although there are currently no international instruments which are legally binding, in force, and specific to climate engineering, numerous components of international law are relevant and have implications of varying clarity for climate engineering. Furthermore, some international legal instruments are specific to climate engineering, but are non-binding or are not yet in force (Gerrard & Hester, 2018).

133. In general terms, two types of risk are related to climate engineering governance and international law. On the one hand, the gap between the global approach that climate action would naturally require and the current international legal order, which is predominantly nation-State based, and the lack of an efficient multilateral agreement could lead some individual governments to unilaterally launch some climate protection actions, and SRM interventions in particular, with a high risk of international disputes (Patrick, 2022). On the other hand, the relatively low cost of SRM (see paragraph 130) makes it available to private entities, such as commercial enterprises, non-State actors, and others (e.g., contractors) without international coordination and consensus (Lockley et al., 2022).

134. The fact that some private companies are indeed moving towards deployment of SRM raises significant scientific, ethical and even legal problems. In April 2022, a start-up company launched balloons into the stratosphere to release sulphur dioxide to make the atmosphere more reflective without having a full understanding of the implications.[5] The aim of this experiment was to attract attention in order to sell 'cooling credits' for profit for future balloon flights. The balloons did not contain any instruments to collect data or to evaluate the effects of the experiment. It was done outside of any legal framework, without consulting local authorities, and with no scientific oversight.

135. The problem of non-State actors is multifaceted and is not just a source of additional risks. The IPCC reports have emphasized that climate change governance includes more than just State activity[6]. Rather it requires a multilevel, polycentric approach from the international to the national level down to cities and communities, using creative methods and participatory processes. This is true in general for all climate actions, and is essential for climate engineering, where risks and challenges are even stronger than for other climate actions – in the sense that it does not only represent a risk, but may also, if appropriately governed, represent an opportunity (Bourzac, 2023).

136. Global agreements on mitigation, adaptation, and climate engineering measures are not easy to conclude or, when signed, to comply with, often for lack of an adequate system of sanctions (as is the case for the Paris Agreement). This should not lead one to underestimate the utility of regionally based agreements among countries belonging to a geographic area and sharing environmental resources or problems (for example where a country upstream on a major river decides to divert it, with serious effects on downstream countries). This applies to mitigation and adaptation measures, as well as to climate engineering techniques, where it is particularly important to assess the unequal spatial distribution of effects (see above, paragraph 63).

137. In this perspective, civil society can also play an important role in pressuring governments and institutions to meet their international obligations. Recent data are significant: "Climate change litigation continues to grow in importance as a way of either advancing

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5 The official statement of the Mexican government is available at the following address: https://www.gob.mx/semarnat/prensa/mexico-antepone-el-principio-precautorio-y-la-justicia-climatica-en-la-experimentacion-con-geoingenieria-solar?idiom=es
See also: https://www.technologyreview.com/2022/12/24/1066041/a-startup-says-its-begun-releasing-particles-into-the-atmosphere-in-an-effort-to-tweak-the-climate/

6 See IPCC AR6 (2022), especially Section 14.4.5 International Governance of SRM and CDR

or delaying effective action on climate change. Globally, the cumulative number of climate change-related cases has more than doubled since 2015. Just over 800 cases were filed between 1986 and 2014, while over 1,000 cases have been brought in the last six years" (Setzer & Higham, 2021). Although there is no evidence yet of lawsuits focused on climate engineering, activism by directly affected individuals and citizens can be seen as an important example of paying cultural attention to these issues, and of ensuring participation by the general public.

VI.
RECOMMENDATIONS

138. Whereas the most important, urgent, and indispensable climate actions are mitigation and adaptation (see above, paragraph 33), COMEST encourages Member States and all relevant stakeholders to adopt the ethical principles outlined in this report when making decisions on climate actions including climate engineering, and recommends the following (not listed in order of importance):

a. **Governance**

ii. Decision-makers should pursue comprehensive, open, and responsible collaboration and constant monitoring of all climate actions, including climate engineering technologies. This is necessary owing to the intrinsic nature of decisions on climate action, which might not be fully ethically defensible in all cases (see paragraph 8).

iii. Decisions on climate action, including climate engineering, should be taken according to an ecosystem-flourishing approach and **intergenerational and distributive justice** considerations.

iv. Decisions on climate engineering techniques should be made considering the **scientific knowledge** on which they are based, the specificity of technology under consideration, the **degree of uncertainty** in the likely outcome of the implementation, the likelihood or otherwise of reversing a proposed deployment, the cultural assumptions and implications, and the **distribution of risks**.

v. Member States have an obligation to **prevent harm** to their citizens, and this includes protecting them from the harmful effects of climate change. Therefore, it is necessary for Member States to **introduce legislation** which, in accordance with international standards (mainly those of the United Nations), regulates climate action, including climate engineering.

vi. Member States should consider the **transboundary impact** of their decisions on all human beings and ecosystems as a global responsibility. As such, they are encouraged to provide and facilitate access to information, and initiate both international and cross-cultural dialogue on such impacts.

vii. Regionally based agreements among countries belonging to a geographic area and shar environmental resources or problems should be encouraged in order to avoid risks of unequal spatial distribution of effects (see paragraph 63).

viii. Any proposal to deploy climate engineering technology should be combined with practical methods of mitigation.

ix. Any use of climate engineering techniques as a weapon (weaponization) should be universally banned.

b. **Participation and inclusiveness**

i. In addition to Member States' efforts at a national level, a **multilevel, polycentric, participatory approach from international cooperation down to regional**

activities within local communities should be encouraged for all climate actions, including climate engineering.

ii. The **innovative, positive engagement of civil society and citizens** as regards climate action, including climate engineering, should be welcomed and encouraged in its participative role, in order to increase democratic pressure on relevant governments and institutions to fulfil their international obligations.

iii. Member States must ensure that **vulnerable**, **neglected, and marginalized individuals and groups, women, youth, and indigenous people** are included as key stakeholders in the development and implementation of policies, decisions, and activities in all matters of climate action governance, and that their interests are properly taken into account.

c. Role of scientific knowledge and research

i. **Scientific research** on climate action, including climate engineering, should be free from unjustified interference by political or economic interests, and have the aim of better identifying and reducing the scientific and societal uncertainties over the efficacy, benefits, and risks of the various technologies.

ii. **Scientific research** on climate change, including climate engineering techniques, should be encouraged when it consists of **indoor research investigations,** involving theoretical analysis, social science research, computer simulations and modelling, and laboratory experiments. In the case of **small-scale outdoor SRM experiments** and **potential large-scale SRM deployments,** in addition to following ethical standards of research, attention must be paid to potential conflicts of interest, transparency and accountability, cultural implications, different disciplinary perspectives, and public engagement.

iii. Any decision on climate action, including climate engineering, should be based on scientific evidence and data (see paragraph 82), and adopt effective **interdisciplinary approaches**.

iv. **Sharing of scientific knowledge and research data** is a global responsibility for anyone involved in climate research, including climate engineering, in order to ensure informed policy-making and public debate on climate change.

v. The impact of climate action including climate engineering technologies in case of deployment, should be regularly monitored to inform decision-makers at all levels.

d. Strengthening capacity

i. Member States should strengthen their **institutional, technological, and ethical capacities** as regards climate action, including climate engineering, and support their public and civic capacity-building activities.

ii. When taking part in climate actions, including climate engineering, business and industry should act ethically, follow relevant international standards, and closely collaborate with public sectors, including local governments and appropriate international organizations.

e. **Education, awareness and advocacy**

i. UNESCO should support ethical issues related to climate action, including climate engineering, as being an integral part of the curricula of relevant **educational and training programs relating to climate science and engineering**.

ii. UNESCO should play a prominent role in **increasing public understanding and awareness** of the ethical challenges associated with climate actions, including climate engineering, and of the importance of scientific and practical uncertainties, and the need for democratic participation and decision-making.

ACRONYMS AND ABBREVIATIONS

AR5, 6 etc.	*IPCC Fifth, Sixth Assessment Report, etc.*
CBD	Convention on Biological Diversity (United Nations)
CDR	carbon dioxide removal
CE	climate engineering
CO_2	carbon dioxide
COMEST	World Commission on the Ethics of Scientific Knowledge and Technology (UNESCO)
DAC	direct air capture
ETC	"The ETC Group monitors the impact of emerging technologies and corporate strategies on biodiversity, agriculture and human rights"
GSMA	Global System for Mobile Communications Association
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change (United Nations)
ISAC	integrated and communication technology
LC/LP	London Convention and London Protocol on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972
NAS	National Academy of Sciences (United States of America)
NASEM	National Academies of Science, Engineering and Medicine
n.d.	no date
NDCs	nationally determined contributions
NETs	negative emissions technologies
NRC	National Research Council (United States of America)
PSAC	President's Science Advisory Committee (United States of America)
RRI	responsible research and innovation
SR1.5	*IPCC Special Report on Global Warming of 1.5ºC* 2
SRM	solar radiation modification
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
WLAN	wireless local area network

BIBLIOGRAPHY

Ackerman, F. (2015). Combating climate change, by the books. *Climate Policy*, 17(3), 397-400. DOI: 10.1080/14693062.2015.1096232

American Geophysical Union (2022). *AGU Climate Intervention Engagement: Leading the Development of an Ethical Framework.*

Asayama, S. & Hulme, M. (2019). Engineering climate debt: temperature overshoot and peak-shaving as risky subprime mortgage lending. *Climate Policy*, 19(8), 937-946. DOI: 10.1080/14693062.2019.1623165

Asayama, S., Hulme, M. & Markusson, N. (2021). Balancing a budget or running a deficit? The offset regime of carbon removal and solar geoengineering under a carbon budget. *Climatic Change*, 167(25). https://doi.org/10.1007/s10584-021-03174-1

Babakhani, P., Phenrat, T., Baalousha, M., Soratana, K., Peacock, C.L., Twining, B.S. & Hochella, M.F. (2022). Potential use of engineered nanoparticles in ocean fertilization for large-scale atmospheric carbon dioxide removal. *Nature Nanotechnology*, 17, 1342–1351.

Banerjee, B. (2011). The limitations of geoengineering governance in a world of uncertainty. *Stanford Journal of Law, Science & Policy*, 4(1), 15–36.

Beck, U. (1992 [1986]). *Risk Society: Towards a New Modernity.* Sage.

Beck, U. (2002 [1995]). *Ecological Politics in an Age of Risk.* Polity Press.

Beck, S. & Mahony, M. (2018). The IPCC and the new map of science and politics. *WIREs Climate Change*, 9(6). doi:10.1002/wcc.547.

Bellamy, R. & Lezaun, J. (2017). Crafting a public for geoengineering. Public *Understanding of Science*, *26*(4), 402–417. https://doi.org/10.1177/0963662515600965

Biermann, F., Oomen, J., Gupta, A., Ali, S. H., Conca, K., Hajer, M. A., Kashwan, P., Kotzé, L. J., Leach, M., Messner, M., Okereke, C., Persson, A., Potočnik, J., Schlosberg, D., Scobie, M. & Van Deveer, S. D. (2022). Solar geoengineering: The case for an international non-use agreement. *WIREs Climate Change*, 13(3). doi.org/10.1002/wcc.754

Biological Weapons Convention. (10 April 1972). Available at: https://disarmament.unoda.org/biological-weapons/

Blackstock, J. (2012). Researchers can't regulate climate engineering alone. *Nature*. 486 (159). https://doi.org/10.1038/486159a

Blackstone, J. & Low, S. (2019). *Geoengineering our Climate? Ethics, Politics, and Governance.* Routledge.

Bonn Declaration on Freedom of Scientific Research (2020). Adopted at the Ministerial Conference on the European Research Area Bonn on 20 October 2020. Available at: https://www.bmbf.de/bmbf/shareddocs/downloads/files/_drp-efr-bonner_erklaerung_en_with-signatures_maerz_2021.pdf?__blob=publicationFile&v=1

Boucher, O., Forster, P. M., Gruber, G., Ha-Duong, M., Lawrence, M. G., Lenton, T. M., Maas, A. & Vaughan, N.E. (2013). Rethinking climate engineering categorization in the context of climate change mitigation and adaptation. *WIREs Climate Change*, 5(1), 23–35. https://doi.org/10.1002/wcc.261.

Bourzac, K. (October 13, 2023). U.S. hands out $7 billion for hydrogen hubs. *Science*, 382(6668). DOI: 10.1126/science.adl4277

Brennan, A. & Norva, Y. S. L. (2022). Environmental ethics. In E.N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy* (Summer 2022 ed.). Stanford University. https://plato.stanford.edu/archives/sum2022/entries/ethics-environmental/

Buck, H. J. (2012). Geoengineering: Re-making climate for profit or humanitarian intervention? *Development and Change*, *43*(1), 253–270. https://doi.org/10.1111/j.1467-7660.2011.01744.x

Callies, D.E. (2019). The slippery slope argument against geoengineering research. *Journal of Applied Philosophy,* 36(4), 675-687.

Caney, S. (2018). Climate Change. In S. Olsaretti (ed.), *The Oxford Handbook of Distributive Justice.* https://doi.org/10.1093/oxfordhb/9780199645121.013.23, accessed 20 Oct. 2023.

Carton, W., Asiyanbi, A., Beck, S., Buck, H. J. & Lund J. F. (2020). Negative emissions and the long history of Carbon Removal. *WIREs Climate Change*, 11(6). https://doi.org/10.1002/wcc.671.

Chemical Weapons Convention. (13 January 1993). Available at: https://www.opcw.org/chemical-weapons-convention

Chhetri, N., Chong, D., Conca, K., Falk, R., Gillespie, A., Gupta, A., Jinnah, S., Kashwan, P., Lahsen, M., Light, M., McKinnon, C., Thiele, L. P., Valdivia, W., Wapner, P., Morrow, D., Turkaly C. & Nicholson, S. (2018). *Governing Solar Radiation Management.* Washington, DC: Forum for Climate Engineering Assessment.

Climate Overshoot Commission (2023). *Reducing the Risk of Climate Overshoot*. Available at the following address: https://www.overshootcommission.org/report

Convention on Biological Diversity. (29 October 2010). Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth meeting. X/33/ Biodiversity and climate change. Available at: https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-33-en.pdf

Convention on Biological Diversity. (9 October 2008). Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Ninth meeting. IX/16/ Biodiversity and climate change. Available at: https://www.cbd.int/doc/decisions/cop-09/cop-09-dec-16-en.pdf

Corner, A. & Pidgeon, N. (2014). Geoengineering, climate change scepticism and the 'moral hazard' argument: an experimental study of UK public perceptions. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences,* 372(2031), 20140063.

Cox, P. M., Huntingford, P. & Williamson, M. S. (2018). Emergent constraint on equilibrium climate sensitivity from global temperature variability. *Nature*, (553), 319–322. https://doi.org/10.1038/nature25450.

Cui, Y., Liu, F., Jing, X. & Mu, J. (2021). Integrating sensing and communications for ubiquitous IoT: Applications, trends, and challenges. *IEEE Network*, 35(5), 158-167.

Dékány, A. (2018). Preston, C.J. (ed.): Climate justice and geoengineering: Ethics and policy in the atmospheric anthropocene. *Hungarian Geographical Bulletin*, 67(2), 191-193. https://doi.org/10.15201/hungeobull.67.2.7

Environmental Protection Agency (1983). *Can We Delay A Greenhouse Warming?.* United States Environmental Protection Agency.

ETC Group. (2010). *Geopiracy: The Case against Geoengineering.*

ETC Group. (2011). *Open letter about the S.P.I.C.E. geoengineering test.*

European Commission (n.d.). *Destination Earth*. Accessed 25 August 2023 from: https://digital-strategy.ec.europa.eu/en/policies/destination-earth.

Felgenhauer, T., Bala, G., Borsuk, M., Brune, M., Camilloni, I., Wiener, J.B., Xu, J. (2022). *Solar Radiation Modification: A Risk-Risk Analysis*. Carnegie Climate Governance Initiative (C2G), New York, NY: www.c2g2.net.

Flegal, J. A., Hubert, A.-M., Morrow, D. R., & Moreno-Cruz, J. B. (2019). Solar geoengineering: Social science, legal, ethical, and economic frameworks. *Annual Review of Environment and Resources*, 44(1), 399–423. https://doi.org/10.1146/annurev-environ-102017-030032

Foley, R. W., Guston, D., & Sarewitz, D. (2018). Towards the anticipatory governance of geoengineering. In J. J. Blackstock & S. Low (eds), *Geoengineering our climate? Ethics, politics and governance* (pp. 223–244). London, England: Routledge.

Gardiner, S. (2007). Environmental Midwifery and the Need for an Ethics of the Transition: A Quick Riff on the Future of Environmental Ethics. *Ethics & the Environment,* 12, 122-123. 10.1353/een.2007.0023.

Gardiner, S. (2011). *A Perfect Moral Storm: The Ethical Tragedy of Climate Change.* Oxford University Press.

Gardiner, S. (2013). Human Rights in a Hostile Climate. In C. Holder (ed.), *Human Rights: the Hard Questions* (pp. 211-230). Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511758553.

Gardiner, S. (2017). Climate Ethics in a Dark and Dangerous Time. *Ethics,* 127(2), 430-465. DOI: https://doi.org/10.1086/688746.

Gerrard, M. & Hester, T. (eds.). (2018). *Climate Engineering and the Law: Regulation and Liability for Solar Radiation Management and Carbon Dioxide Removal*. Cambridge: Cambridge University Press. doi:10.1017/9781316661864.

Gosseries, A. (2001). What do we owe the next generation(s)?. *Loyola of Los Angeles Law Review*, 35, 293–354.

GSMA. (2023). *The Mobile Economy 2023.*

Gunderson, R., Stuart, D., Petersen, B. & Yun, S. (2018). Social conditions to better realize the environmental gains of alternative energy: Degrowth and collective ownership. *Futures*. 99, pp. 36-44. https://doi.org/10.1016/j.futures.2018.03.016

Gupta, A. & Moller, I. (2018). De facto governance: How authoritative assessments construct climate engineering as an object of governance. *Environmental politics,* 28(3), 480-50.

Hegerl, G.C. & Solomon S. (2009). Risks of climate engineering. *Sciencexpress*. 10.1126/science.1178530

Herzog, M. & Parson, E. T. A. (2016). Moratoria for global governance and contested technology: The case of climate engineering. *UCLA School of Law, Public Law Research Paper.* 16-17.

Hourdequin, M. (2018). Climate change, climate engineering, and the 'global poor': What does justice require? *Ethics Policy & Environment,* 21(6), 1-19. DOI:10.1080/21550085.2018.1562525

Hubert A. (2021). A code of conduct for responsible geoengineering research. *Global Policy*, 12, Suppl.1, 82-96. doi: 10.1111/1758-5899.12845

International Covenant on Economic, Social and Cultural Rights (16 December 1966). General Assembly resolution 2200A (XXI). Entered into force 3 January 1976. Available at: https://www.ohchr.org/en/instruments-mechanisms/instruments/international-covenant-economic-social-and-cultural-rights

Irvine, P.J., Ridgwell, A. & Lunt, D. J. (2011). Climatic effects of surface albedo geoengineering. *Journal of Geophysical Research: Atmospheres*. 116(D24).

Irvine, P. J., Kravitz, B., Lawrence, M. G. & Muri, H. (2016). An overview of the Earth system science of solar geoengineering. *WIREs Climate Change,* 7 (6), 815-833.

Irvine, P.J. & Keith, D. W. (2020). Halving warming with stratospheric aerosol geoengineering moderates policy-relevant climate hazards. *Environmental Research Letters*, 15(4), 044011, https://doi.org/10.1088/1748-9326/ab76de.

Intergovernmental Panel on Climate Change (IPCC) (2014). Climate change 2014: Synthesis report. In R.K. Pachauri & L.A. Meyer (eds), *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*

Intergovernmental Panel on Climate Change (IPCC) (2018). Global warming of 1.5°C. In V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor & T. Waterfield (eds), *An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.*

Intergovernmental Panel on Climate Change (IPCC) (2021). Summary for Policymakers. In V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu & B. Zhou (eds), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. In press.

Intergovernmental Panel on Climate Change (IPCC) (2023). Summary for policymakers. In H. Lee & J. Romero (eds), *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. (pp. 1-34). doi: 10.59327/IPCC/AR6-9789291691647.001

Jebari, J., Táíwò, O.O., Andrews, T. M., Aquila, V., Beckage, B., Belaia, M., Clifford, M., Fuhrman, J., Keller, D. P., Mach, K. J., Morrow, D. R., Raimi, K. T., Visioni, D., Nicholson, S. & Trisos, C.H. (2021). From moral hazard to risk-response feedback. *Climate Risk Management,* 33, 100324. https://doi.org/10.1016/j.crm.2021.100324.

Jones, R. (2003). Managing climate change risks. *OECD Workshop on the Benefits of Climate Policy: Improving Information for Policy Makers.* Organisation for Economic Co-operation and Development. Available at: https://www.oecd.org/env/cc/19519189.pdf

Keith, D. W. (2013). *A Case for Climate Engineering*. MIT Press.

Keller, D., Feng, E. & Oschlies, A. (2014). Potential climate engineering effectiveness and side effects during a high carbon dioxide-emission scenario. *Nature Communications* 5, 3304. https://doi.org/10.1038/ncomms4304

Klein, N. (2014). *This Changes Everything: Capitalism vs. the Climate.* New York: Simon & Shuster.

Kopnina, H., Washington, H., Taylor, B. et al. (2018). Anthropocentrism: More than just a misunderstood problem. *Journal of Agricultural & Environmental Ethics,* 31, 109–127. https://doi.org/10.1007/s10806-018-9711-1

Kuo, S. (2011). Climate change and the ecological intelligence of Confucius. *Journal of Global Ethics*, 7(2), 185-194.

Lamont, J. & Favor, C. (2017). Distributive Justice. In E.N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy* (Winter 2017 edition). https://plato.stanford.edu/archives/win2017/entries/justice-distributive.

Langlois, A. (2017). The global governance of human cloning: The case of UNESCO. *Palgrave communications*, 3(1), 1-8. https://unesdoc.unesco.org/ark:/48223/pf0000180356.

Lawrence, M. G., & Crutzen, P. J. (2017). Was breaking the taboo on research on climate engineering via albedo modification a moral hazard, or a moral imperative? *Earth's Future*, *5*(2), 136–143. https://doi.org/10.1002/2016ef000463

Lawrence, M.G., Schäfer, S., Muri, H. Scott, V., Oschlies, A., Vaughan, N. E., Boucher, O., Schmidt, H., Haywood J. & Scheffran, J. (2018). Evaluating climate geoengineering proposals in the context of the Paris Agreement temperature goals. *Nature Communications,* 9(3734). doi.org/10.1038/s41467-018-05938-3

Lockley, A., Xu, Y., Tilmes, S., Sugiyama, M., Rothman, D., & Hindes, A. (2022). 18 Politically relevant solar geoengineering scenarios. *Socio-Environmental Systems Modelling*, 4 (18127). doi:10.18174/sesmo.18127

Long, J. C. S., Rademaker, J. G., Anderson, J. G., Benedick, R. E., Caldeira, K., Chaisson, J. & Winickoff, D. E. (2012). *Geoengineering: A National Strategic Plan for Research on the Potential Effectiveness, Feasibility, and Consequences of Climate Remediation Technologies.* Washington, DC: Task Force on Climate Remediation Research, Bipartisan Policy Center.

Long, J. C. S. & Shepherd, J. G. (2014). The strategic value of geoengineering research. In B. Freedman (eds), *Global Environmental Change: Handbook of Global Environmental Pollution* (Vol 1). Dordrecht: Springer.

Long J. C. S. (2017). Coordinated action against climate change: A new world symphony. *Issues in Science and Technology,* 33(3). https://issues.org/coordinated-action-against-climate-change-a-new-world-symphony/.

Low, S. & Buck, H.J. (2020). The practice of responsible research and innovation in "Climate engineering". *WIREs Climate Change*, 11(3). doi:10.1002/wcc.644.

Lund, M.T., Myhre, G., Skeie, R.B., Samset, B.h., & Klimont, Z. (2023). Implications of differences between recent anthropogenic aerosol emission inventories for diagnosed AOD and radiative forcing from 1990 to 2019. *Atmospheric Chemistry and Physics*, 23(12), 6647–6662. doi:10.5194/acp-23-6647-2023.

MacMartin, D. G., Wang, W., Kravitz, B., Tilmes, S., Richter, J. H., & Mills, M. J. (2019). Timescale for detecting the climate response to stratospheric aerosol geoengineering. *Journal of Geophysical Research: Atmospheres*, 124(3), 1233–1247. doi:10.1029/2018jd028906.

McLaren, D. (2016). Mitigation deterrence and the "moral hazard" of solar radiation management. *Earth's Future,* 4, 596–602. doi:10.1002/2016EF000445.

Meyer, L. (2021). Intergenerational Justice. In E.N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy.* (Summer 2021 edition). Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/sum2021/entries/justice-intergenerational/

Meyer, L. & Roser, D. (2006). Distributive Justice and Climate Change. The allocation of emission rights. *Analyse & Kritik*, 28(2), 223-249. https://doi.org/10.1515/auk-2006-0207

Médecins sans frontières. (n.d.). *The Practical Guide to Humanitarian Law.* Available at: https://guide-humanitarian-law.org/content/article/3/proportionality/

Ming, T., Liu, W. & Caillol, S. (2014). Fighting global warming by climate engineering: Is the Earth radiation management and the solar radiation management any option for fighting climate change? *Renewable and Sustainable Energy Reviews,* 31, 792-834.

Morrow, D. R. (2017). *International Governance of Climate Engineering: A Survey of Reports on Climate Engineering, 2009–2015.* (Working paper series 001. SSRN: 2982392). Forum for Climate Engineering Assessment.

National Academies of Sciences, Engineering and Medicine (NASEM) (2015a). *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration*. The National Academies Press.

National Academies of Sciences, Engineering and Medicine (NASEM) (2015b). *Climate Intervention: Reflecting Sunlight to Cool Earth*. The National Academies Press.

National Academies of Sciences, Engineering, and Medicine (NASEM) (2021). *Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25762.

National Research Council (NRC) (1977). *Energy and Climate: Studies in Geophysics*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12024.

National Research Council (NRC) (1983). *Changing Climate: Report of the Carbon Dioxide Assessment Committee*. The National Academies Press. https://doi.org/10.17226/18714.

National Research Council (NRC) (2015a). *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration*. The National Academies Press. https://doi.org/10.17226/18805.

National Research Council (NRC) (2015b.) *Climate Intervention: Reflecting Sunlight to Cool Earth*. The National Academies Press. https://doi.org/10.17226/18988.

National Academies of Science, Engineering and Medicine (2021). *Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance*. The National Academies Press. https://doi.org/10.17226/25762

Neuber, F. & Ott, K. (2020). The buying time argument within the solar radiation management discourse. *Applied Sciences*, 10(13):4637. https://doi.org/10.3390/app10134637

Neuteleers, S. (2022). Trading nature: When are environmental markets (un)desirable? *Journal of Political Philosophy*, 30(1), 116-139.

Nightingale, P. & Cairns, R. (2014). *The Security Implications of Geoengineering: Blame, Imposed Agreement and the Security of Critical Infrastructure.* Climate Geoengineering Governance Working Paper Series 18. Sussex University.

Owen, R., Macnaghten, P. & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy,* 39(6), 751–760. https://doi.org/10.1093/scipol/scs093

Owen, R. (2014). Solar radiation management and the governance of hubris. In R. M. Harrison & R. E. Hester (eds), *Geoengineering of the Climate System* (pp. 212–248). Royal Society of Chemistry.

Pamuk, Z. (2021). Risk and fear: Restricting science under uncertainty. *Journal of Applied Philosophy,* 38(3), 444-460.

Pamplany, A., Gordijn, B. & Brereton, P. (2020). The ethics of geoengineering: A literature review. *Science and Engineering Ethics,* 26, 3069–3119.

Paris Agreement to the United Nations Framework Convention on Climate Change [Dec 12, 2015], T.I.A.S. No. 16-1104.

Pasztor, J. (2022). *Calls for an SRM 'non-use agreement' underline the need for governance.* C2G. Available at: https://www.c2g2.net/calls-for-an-srm-non-use-agreement/

Patt, A., L. Rajamani, P. Bhandari, A. Ivanova Boncheva, A. Caparrós, K. Djemouai, I. Kubota, J. Peel, A.P. Sari, D.F. Sprinz & J. Wettestad. (2022). International cooperation. In P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz & J. Malley, (eds), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. doi: 10.1017/9781009157926.016

Patrick, S. M. (2022). *Reflecting Sunlight to Reduce Climate Risk*. (Council Special Report No. 93). Council on Foreign Relations. Available at: https://www.cfr.org/report/reflecting-sunlight-reduce-climate-risk

Poel, I., Fahlquist, J., Doorn, N., Zwart, S. & Royakkers, L. (2011). The problem of many hands: Climate change as an example. *Science and Engineering Ethics*. 18. 49-67. 10.1007/s11948-011-9276-0.

President's Science Advisory Committee (PSAC) (1965). *Restoring the Quality of Our Environment,* Washington D.C.: The White House. Available at: https://www-legacy.dge.carnegiescience.edu/labs/caldeiralab/Caldeira%20downloads/PSAC,%201965,%20Restoring%20the%20Quality%20of%20Our%20Environment.pdf

Preston, C.J. (2013). Ethics and geoengineering: Reviewing the moral issues raised by solar radiation management and carbon dioxide removal. *Wiley Interdisciplinary Reviews: Climate Change,* 4(1), 23-37.

Proelss, A. & Steenkamp, R.C. (2023), Geoengineering: Methods, associated risks and international liability corporate liability for transboundary environmental harm. In P. Gailhofer, D. Krebs, A. Proelss, K. Schmalenbach, R. Verheyen (eds), *Corporate Liability for Transboundary Environmental Harm* (pp. 419–503). Springer Cham. https://doi.org/10.1007/978-3-031-13264-3.

Randers, J. & Goluke, U. (2020). An earth system model shows self-sustained thawing of permafrost even if all man-made GHG emissions stop. *Scientific Reports,* 10, 18456. https://doi.org/10.1038/s41598-020-75481-z

Rayner, S., Heyward, C., Kruger, T., Pidgeon, N., Redgwell, C. & Savulescu, J. (2013). The Oxford Principles. *Climatic Change,* 121, 499–512. https://doi.org/10.1007/s10584-012-0675-2

Resnik, D.B. & Vallero, D.A. (2011). Geoengineering: An idea whose time has come? *Journal of Earth Science & Climatic Change*, 1(1), PMID: 23502911; PMCID: PMC3596048.

Resolution LP.4(8) on the amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities (2013). LP.8. LC 35/15. Annex 4. Annex 5. 2013. Available at: https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/LCLPDocuments/LP.4(8).pdf

Reynolds, J. (2015). A critical examination of the climate engineering moral hazard and risk compensation concern. *The Anthropocene Review*, 2(2), 174-191. https://doi.org/10.1177/2053019614554304

Reynolds, J. L. (2019). Solar geoengineering to reduce climate change: A review of governance proposals. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 475(2229), 20190255.

Robock, A., Bunzl, M., Kravitz, B. & Stenchikov, G.L. (2010) A test for geoengineering? *Science*, 327(5965), 530-531.

Roeser, S., Taebi, B. & Doorn, N. (2020). Geoengineering the climate and ethical challenges: What we can learn from moral emotions and art. *Critical Review of International Social and Political Philosophy,* 23(5), 641-658.

Sandel, M. J. (2013). Market reasoning as moral reasoning: Why economists should re-engage with political philosophy? *The Journal of Economic Perspectives.* 27(4), pp.121-140. http://dx.doi.org/10.1257/j

Sarewitz, D. (2004). How science makes environmental controversies worse. *Environmental Science & Policy,* 7(5), 385-403. https://doi.org/10.1016/j.envsci.2004.06.001

Setzer, J. & Higham, C. (2021). *Global Trends in Climate Change Litigation: 2021 Snapshot.* London: Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, London School of Economics and Political Science.

Smith, W. (2020). The cost of stratospheric aerosol injection through 2100. *Environmental Research Letters*. 15 (11): 114004

Solomon, S., Plattner, G.-K., Knutti, R. & Friedlingstein, P. (2009). Irreversible climate change due to carbon dioxide emissions. *Proceedings of the National Academy of Sciences (PNAS),* 106(6), 1704-1709.

Stern, N. (2007). *The Economics of Climate Change: The Stern Review.* Cambridge University Press.

Svoboda, T., Keller, K., Goes, M. & Tuana, N. (2011). Sulfate aerosol geoengineering: The question of justice. *Public Affairs Quarterly,* 25(3), 157-179.

Svoboda, T. & Irvine, P. (2014). Ethical and technical challenges in compensating for harm due to solar radiation management geoengineering. *Ethics, Policy & Environment,* 17(2), 157-174.

Svoboda, T. (2016). Climate engineering and human rights. *Environmental Politics,* 28(3), 397-416.

Taebi, B., Kwakkel, J. H. & Kermisch, C. (2020). Governing climate risks in the face of normative uncertainties. *WIREs Climate Change*, 11(5). doi:10.1002/wcc.666.

Talberg, A., Christoff, P., Thomas, S., & Karoly, D. (2017). Geoengineering governance-by-default: An earth system governance perspective. *International Environmental Agreements: Politics, Law and Economics*, 18(2), 229-253.

Tan, D. K. P., He, J., Li, Y., Bayesteh, A., Chen, Y., Zhu, P. & Tong, W. (2021). *Integrated sensing and communication in 6G: Motivations, use cases, requirements, challenges and future directions: 1st IEEE International Online Symposium on Joint Communications & Sensing (JC&S)* (pp. 1-6). IEEE.

Terblanché-Greeff, A. (2019). Ubuntu and environmental ethics: The West can learn from Africa when faced with climate change. In M. Chemhuru (ed.), *African Environmental Ethics: A Critical Reader* (pp. 93-109). Springer Verlag.

The Royal Society (2009). *Geoengineering the climate: science, governance and uncertainty.* Available at: https://royalsociety.org/~/media/RoyalSocietyContent/policy/publications/2009/8693.pdf.

The Royal Society (2021a). *A Net Zero Climate-Resilient Future: Science, Technology and the Solutions for Change.* Statement by the Royal Society. Available at: https://royalsociety.org/-/media/policy/projects/climate-change-science-solutions/climate-science-solutions-overview.pdf

The Royal Society (2021b). *Next generation climate models: A step change for net zero and climate adaptation. Briefing by the Royal Society.* Available at https://royalsociety.org/-/media/policy/projects/climate-change-science-solutions/climate-science-solutions-modelling.pdf

The White House (November 8 2022). *Fact sheet: Biden-Harris administration announces roadmap for nature-based solutions to fight climate change, strengthen communities, and support local economies.* Available at: https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/08/fact-sheet-biden-%E2%81%A0harris-administration-announces-roadmap-for-nature-based-solutions-to-fight-climate-change-strengthen-communities-and-support-local-economies/

United Nations Educational, Scientific and Cultural Organization (UNESCO). (1997). *Universal Declaration on the Human Genome and Human Rights.* Available at: https://www.unesco.org/en/legal-affairs/universal-declaration-human-genome-and-human-rights (especially Art. 11)

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2010). *Ocean Fertilization: A Scientific Summary for Policy Makers.* Intergovernmental Oceanographic Commission (IOC) of UNESCO. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000190674

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2017). *Declaration of Ethical Principles in relation to Climate Change.* Available at: https://unesdoc.unesco.org/ark:/48223/pf0000260129

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2020). *Preliminary Report on the first Draft of the Recommendation on the Ethics of Artificial Intelligence.* Available at: https://unesdoc.unesco.org/ark:/48223/pf0000374266

United Nations Environment Programme (UNEP) (2022). *Emissions Gap Report 2022: The Closing Window — Climate crisis calls for rapid transformation of societies.* Nairobi. https://www.unep.org/emissions-gap-report-2022

United Nations Environment Programme (UNEP) (2023). *One Atmosphere: An Independent Expert Review on Solar Radiation Modification Research and Deployment.* Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/41903/one_atmosphere.pdf?sequence=3&isAllowed=y

van Beek, L., Milkoreit, M., Prokopy, L., Reed, J.B., Vervoort, J., Wardekker, A. & Weiner, R. (2022). The effects of serious gaming on risk perceptions of climate tipping points. *Climatic Change,* 170**,** 31. https://doi.org/10.1007/s10584-022-03318-x.

Wang, J., Varshney, N., Gentile, C., Blandino, S., Chuang, J. & Golmie, N. (2022). Integrated sensing and communication: Enabling techniques, applications, tools and data sets, standardization, and future directions. *IEEE Internet of Things Journal*, 9(23), 23416-23440.

Wei, J., Bin, H., Habibi, M. A. & Schotten, H. D. (2021). The Road Towards 6G: A Comprehensive Survey. *IEEE Open Journal of the Communications Society*, 2, 334-366. doi: 10.1109/OJCOMS.2021.3057679.

World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) (2010-2015). *Ethical Principles for Climate Change: Reports of the World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) of UNESCO*. Available at : https://unesdoc.unesco.org/ark:/48223/pf0000245280_eng.

World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) (2021). *Report of the Ethical Implications of the Internet of Things (IoT)*. Report adopted in September 2021.

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THE ETHICS OF
CLIMATE ENGINEERING

Climate engineering relates to a broad set of methods and technologies that aim to deliberately alter the climate system to alleviate the impacts of climate change. While these technologies have the potential to stabilise and reduce global temperatures, their emergence raises fundamental ethical questions, with deep concerns regarding the lack of research on their environmental impact, as well as the current lack of governance which could lead to potential geopolitical tensions, human rights implications, and unequal distribution of harm and benefits amongst societies.

The report of the World Commission on the Ethics of Scientific Knowledge and Technology of UNESCO proposes a comprehensive ethical perspective on climate engineering. Based on reflection about what the research, development and deployment of such new technologies could imply for both the present and future generations, the Commission raises awareness about the potential risks and benefits of these technologies and lists recommendations which can offer suggestions about normative ethics in this field.

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